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Journal
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Vol. 203 MARCH, 1927 No. 3

INTERMITTENT VALVE OSCILLATOR.*

BY

LAURISTON S. TAYLOR, A.B.

Department of Physics, Cornell University.

By INTERMITTENT valve oscillator is here meant an oscillating circuit maintained by a thermionic valve which oscillates only during certain definite intervals of time. The periods of normal oscillation when interspersed by intervals of silence will be termed "zules." (In a previous paper, the somewhat misleading term of "beat" was applied to the same effect, but this designation will be discontinued.[1]) The effect may be procured by the insertion of proper high resistance and capacitance into the grid circuit of an oscillator, and various studies of the phenomena have been previously reported.[2, 3]

The circuit used in this study is of a modified Hartley type (Fig. 1). Ordinarily such a circuit requires no blocking condenser before the grid, in order to maintain the mean grid potential at a value sufficiently negative to give strong oscillations. However, such a condenser properly shunted by a moderately high resistance may be inserted between the grid and filament in several ways without seriously modifying the oscillation characteristics of the circuit, provided that the resistance does not exceed some

* Submitted for publication, May 18, 1926.

[1] L. S. TAYLOR, *J. O. S. A.* and *R. S. I.*, 11, 149–159 (1926).

[2] BEATY and GILMOUR, *Phil. Mag.*, 40, 291–298 (1920).

[3] RSCHEWSKIN and WEDENSKY, *Phys. Zeit.*, 23, 150–152 (1922).

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

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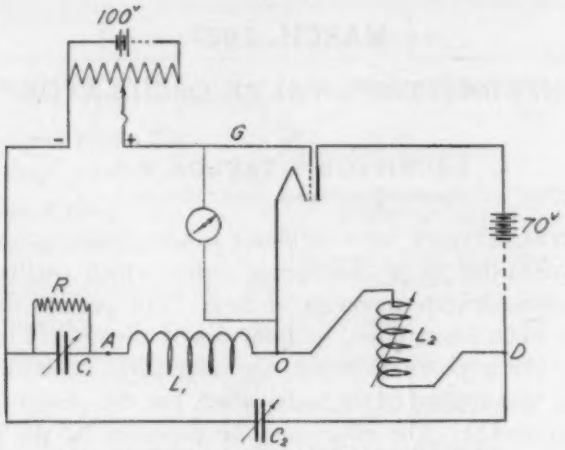
definite maximum value. When the resistance exceeds this value, the oscillations are interrupted by periods of silence.

In this study, a high resistance of very constant value and a variable mica condenser in parallel were placed in the circuit as shown in the figure. As will be seen, this location of R and C_1 has a double effect. First, it isolates the grid from the remainder of the circuit, thus preventing any flow of charge from the grid,

FIG. 1.



Oscillating circuit with variable grid-biasing potential.

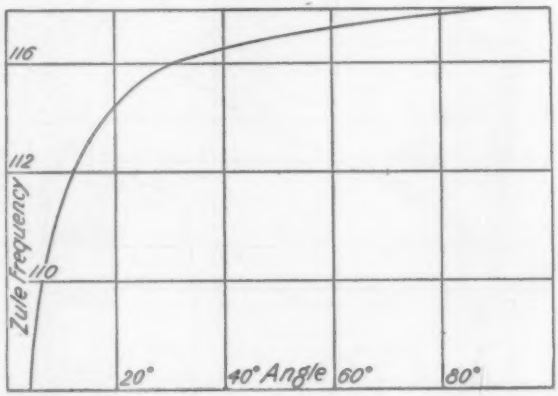
except through R. Secondly, it modifies the main oscillating circuit $L_1L_2C_2$ by the addition of the second capacity C_1. For the most part, however, C_1 was of the order of .5 μf while C_2 was of the order of 50–500 μμf and so the effect of the former capacitance upon the frequency and intensity of oscillations was quite small. The effects described below occur similarly when R and C_1 are placed immediately next to the grid.

EXPERIMENTAL RESULTS.

This study has been principally on the effect of the changes of C_1, C_2, L_1, and L_2 on the zule frequency and of the shape of their characteristic curves. For purposes of clearness, I will consider the whole as a network of three circuits, each pair having a branch in common. The circuit containing the grid, filament, C_1 and L_1, will be referred to as the grid circuit; the circuit containing the plate, L_2 and the filament as the plate circuit; and circuit L_2, C_2,

C_1 and L_1 as the oscillating circuit. C_2 is a variable air condenser, shunted by a variable mica condenser. L_1 is a pan-cake type of step inductor, and L_2 a Brooks inductometer. R was fixed at 1 meg-ohm and C_1 usually at .5 to .8 μf. In roughly exploring the characteristics of the circuit for various changes in inductance and capacitance, it was observed that in certain regions the zule frequency was extremely sensitive to small capacity changes or small inductance changes. For this reason the entire circuit was

FIG. 2.



Curve showing effect on zule frequency, of coupling between L_1 and L_2 in terms of the angle between coils.

inclosed in a metal box and the negative side of the filament grounded to the box.

It was found that the zule frequency depended upon the degree of coupling between L_1 and L_2. Fig. 2 shows a curve of zule frequency against the angle between two inductances of the pan-cake type, thus giving a qualitative idea of the effect of coupling on the zule frequency F. Since it was desired to adjust both L_1 and L_2, they were separated by a distance sufficient to insure negligible coupling between them.

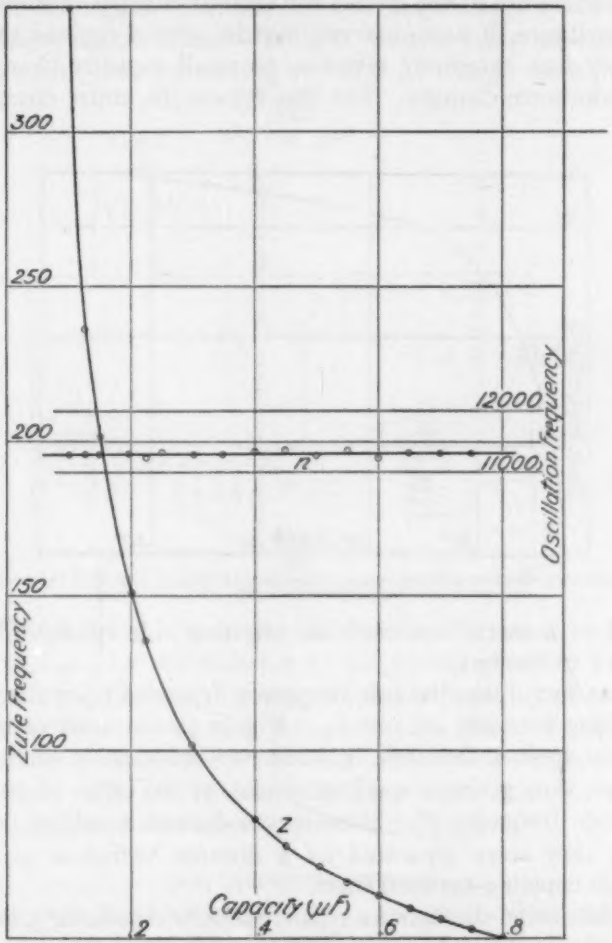
To detect the oscillations a pair of high-impedance phones in series with a small coil was coupled loosely to L_1. Loose coupling was very necessary, for otherwise variations in capacity of the phone circuit altered the critical operation of the oscillator.

Fig. 3 shows the zule frequency as a function of C_1. The shape of this curve is what would be expected, showing that as the capacitance is increased, a greater amount of charge must be

accumulated in order to stop the oscillation, and thus the periods of normal oscillation would occur less often.

The critical regions of oscillation are dependent prinicipally

FIG. 3.

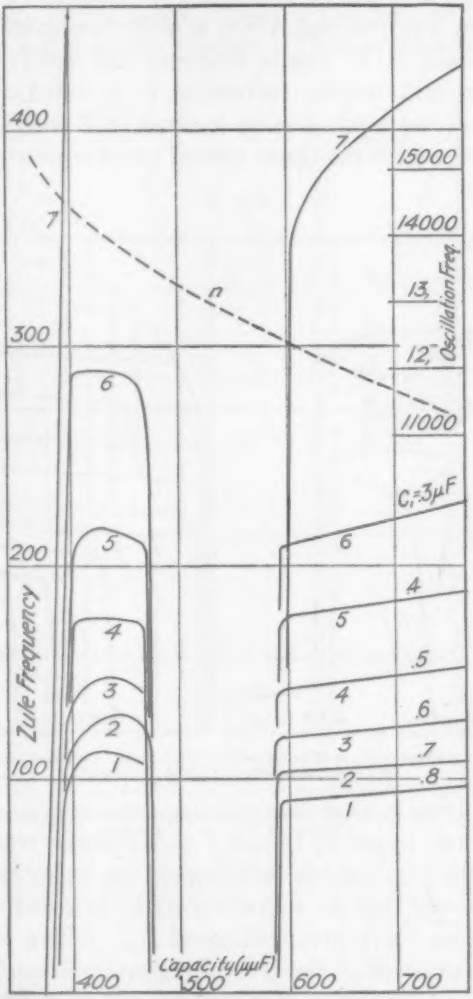


Curve *Z*—Effect of capacity C_1 on zule frequency. Curve *N*—Oscillation frequency of the circuit corresponding to changes in C_1.

upon the values of the inductances L_1 and L_2 and the capacitance C_2. The curves in Fig. 4 show the variation of zule frequency with capacitance C_2, each curve being for a different fixed value of C_1. In parallel with C_2 was a second capacitance of 5000 μμf.

As C_2 was increased up to a certain critical value, the circuit was oscillating normally in a steady state. Upon reaching this critical

FIG. 4.

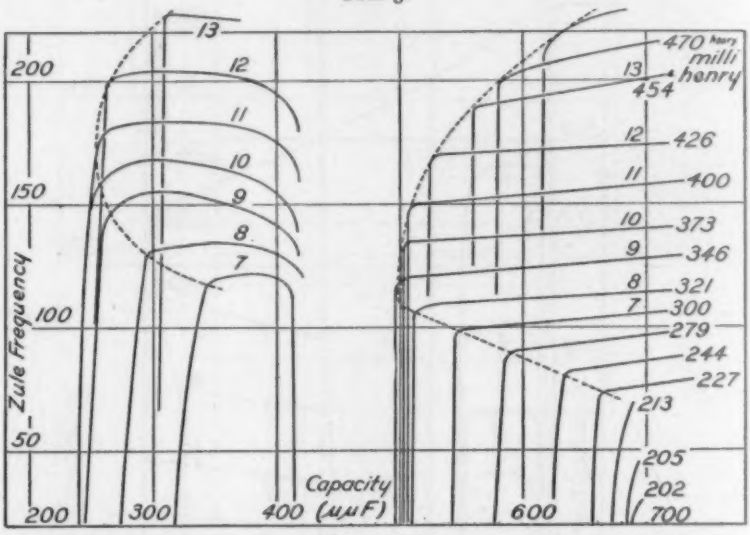


Curves 1–7, showing effect of capacity C_2 on zule frequency, for different values of C_1 (*i.e.*, for curve 6, C_1 = .3 μf; curve 5, C_1 = .4 μf, etc.). Curve *N*—Oscillation frequency corresponding to changes in C_2 along curve 1.

value, however, the oscillations were no longer steady, but became intermittent. This transition point is very sharply defined, being

of the order of 1/1000 μμf change in capacity. A very small further increase in C_1 produced a large increase in the zule frequency F up to a certain value. Here the change of F with C_2 became smaller and passed through a maximum. Then a second critical region was reached, when a slight increase in C_2 caused a large decrease in F, finally reaching the steady state region again. Upon still further increasing C_2 a third critical region was entered, giving again a large increase in F with small increase in C_2. In this region the upper cut-off point is much more clearly

FIG. 5.



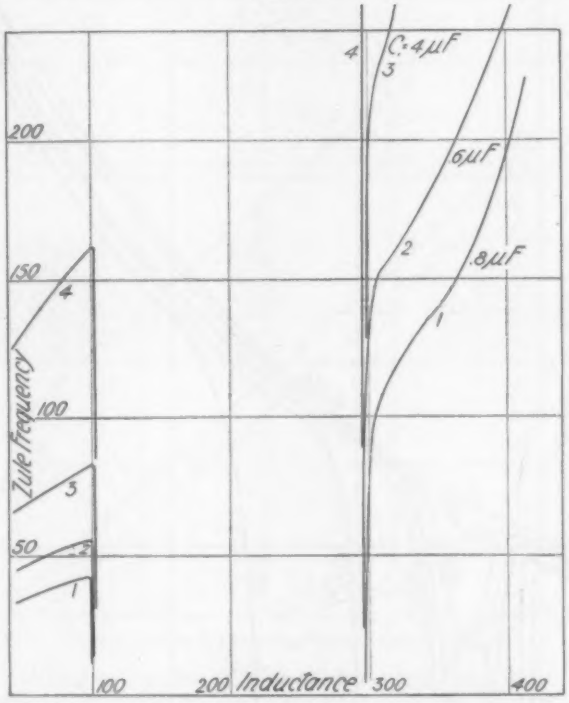
Curves showing effect of C_2 on zule frequency for different values of inductances L_2. (Inductance values of L_2 given on right.)

defined, and after having been passed, the increase of F with C_2 is very slow and seems to follow a nearly linear relation. There are several other factors to be observed on these curves. First, it will be observed that the sole effect of C_1 is a shift of the actual zule frequencies for a given value of C_2. There is little or no change in the position of the critical regions. Secondly, the upper cut-off values in the first critical regions are considerably broader than in the other regions. Thirdly, the maximum point and the first two upper cut-off values are at greater zule frequencies than the third cut-off.

At the same values of the capacitance C_2 the zule frequencies

were determined for the various values of C_1 (Fig. 4). Then plotting $\log_e F$ against $\log_e C_1$ a straight line resulted, of which the slope was very nearly minus 1. This was also checked out by a similar plot from the curve in Fig. 3, but the principal value in the curves of Fig. 4 was in showing that this relation of F to C_1 held in the entire region studied. Thus was obtained the sim-

FIG. 6.



Effect of inductance L_2 on zule frequency, for different values of capacity C_1. (L_2 in millihenrys. F in zules per minute.)

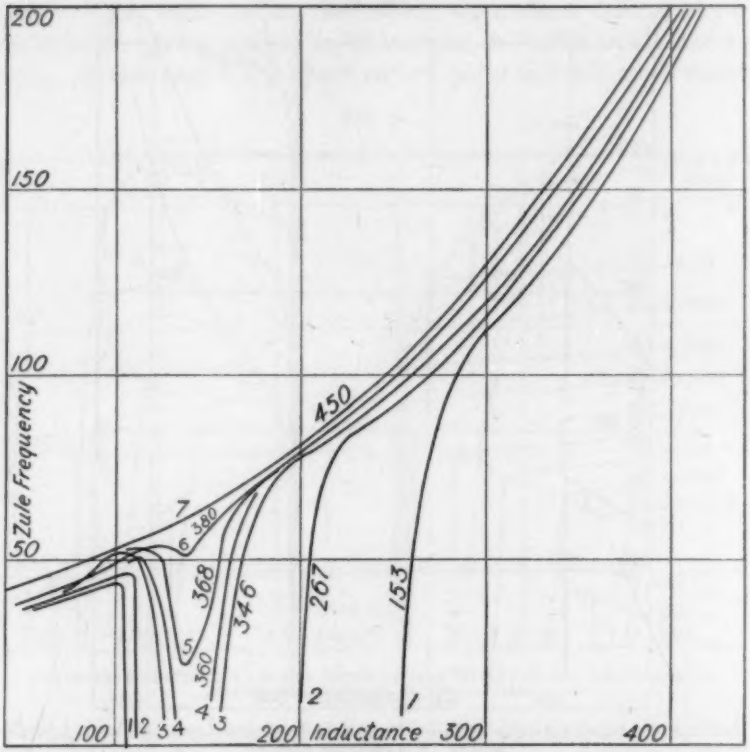
ple relation between the zule frequency and the capacitance C_1, namely that:

$$F \propto \frac{1}{C_1} \qquad (1)$$

A different type of variation may be brought out when C_2 is varied, for different fixed values of L_2 and L_1. The curves in Fig. 5 show these relations. In referring to the upper cut-off values as before, it will be seen that these occur now at different values of C_2 for different values of L_2 except for the second

region which seems to remain constant. As the fixed values of L_2 decrease, the second region cut-offs occur at a lower value of C_2 passing through a minimum and then occurring at higher values of C_2. The envelope of the cut-off points seems to follow a parabolic path. As L_2 increases the cut-offs occur at progres-

FIG. 7.



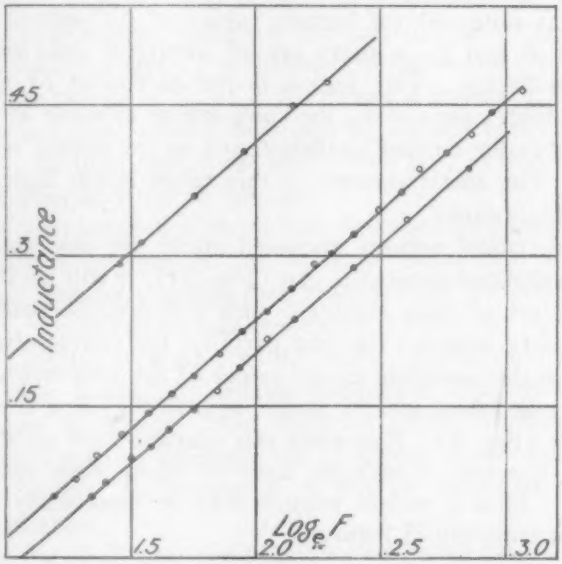
Curves showing change of zule frequency with inductance L_2 for different values of C_2. (Values of C_2 in $\mu\mu$ F given by each curve. L_2 in millihenrys. F in zules per minute.)

sively higher zule frequencies. In the third region, up to a certain maximum value of L_2 the cut-offs are linear with L_2, while above this maximum, the envelope again appears to be of parabolic form.

Fig. 6 shows the characteristics of F against the inductance L_2, each curve being for a different fixed value of C_1. Here within the range studied are two or sometimes three critical regions. If for a certain fixed value of C_1 and C_2, the inductance L_2 be increased, there is steady but not rapid increase in F up

to a very critical value of L_2, at which there is a very large decrease in the zule frequency for a slight increase in the inductance. Again the oscillator reaches a steady state over a certain range of L_2, after which a second critical region is attained where there is a large increase in F for a slight increase in L_2. The critical value of L_2 for the first region appears to be fixed for various values of C_1 and the second region appears to vary but

FIG. 8.



Linear relation between $\log_e F$ and L_2 (see equation 2).

slightly. After increasing L_2 beyond the second region, it will be observed that the curve passes through a point of inflection and then becomes increasingly steeper. A point brought out by this particular family of curves is to show that the capacity C_1 has no effect on the zule frequency other than one of increasing it according to the inverse relation found before.

The effect of inductance variations for different fixed values of C_2 brings out relationships that are more easy to study. Again, there are two or three critical regions, within the range studied, of the same type as discussed above. Such a family of curves of F against L_2 are shown in Fig. 7. There are several important points to be noted in this connection. First, the critical regions

occur at different values of L_2 and come nearer to each other as the values of C_2 increase. However, it will also be noted that the first region shifts but slightly toward higher values of L_2, while the second region shifts very rapidly to lower values of L_2. Secondly, these critical regions, after a certain value of C_2 has been exceeded, merge, and the interval of normal oscillation disappears. Beyond this point the deviation from the main characteristic decreases and finally disappears altogether.

Within the range of inductance available, a third critical region was observed for certain values of C_2, where for high values of F and L_2 a sharp cut-off occurred, followed by the steady oscillation. This region is the narrowest of the three. For very high values of F_1 the zules appear to occur at the same frequency as the normal oscillation and so the critical region disappears. The zule frequency in this range is too high to count by ordinary means.

If the critical regions discussed above are neglected, and a curve interpolated across the gap (Fig. 12), it will be found that for every set of data obtained, such interpolation will form a smooth curve between the two parts of the characteristics. If then, from this complete curve, values of the zule frequency and inductance be taken, and L_2 plotted against $\log_e F$, a straight line will result (Fig. 8). Repeating this operation for all the curves will give a series of straight lines of equal slope but varying intercept. Thus a second relation may be empirically obtained, giving the exponential form:

$$F = A\varepsilon^{\frac{L_2 - b}{m}} \tag{2}$$

where m is the slope of the curves and is constant for all values of C_2, b is a constant obtained from the intercept, depends upon the value of C_2 and may be determined from the set of straight line relations plotted above. By plotting the intercepts of these curves on the L_2 axis, against the corresponding values of C_2, a straight line again results, thus determining that $b = kC_2$, where k is a new constant. Thus a final relation is obtained, giving

$$F = A\varepsilon^{\frac{L_2 - kC_2}{m}}. \tag{3}$$

From the dimensions of equation (3), it is seen that A must be a reciprocal frequency. The slope m has the dimension of

an inductance and is equal to $2\ L_1$. Also k must be a resistance squared.

It is of interest to note to what degree the zule frequency during the critical regions is dependent upon changes in L_2 and C_2.[1] Thus in the first region (Fig. 6), a change in inductance of 1 millihenry will cause a change of 100 in the zule frequency per minute. Since a change of 1 zule per minute is easily detected, a change in L_2 of .01 millihenry may be detected, being a change of 1 part in 10,000. The same is approximately so within the second critical region. Similarly for capacity, there is great sensitivity to small changes. For instance, in the second critical region (Fig. 4), a change in C_2 of 2 μμf causes a change of 100 in the zule frequency per minute, thus making .02 μμf easily detectable. However, the total capacity is about 6000 μμf, so that the change is of the order of 1 part in 300,000.

With such sensibility, the circuit discussed may be of considerable practical importance. It must be noted that the normal oscillation frequency within each zule changes for every value of L and C. However, as was previously pointed out by the writer for the Colpitts type of circuit,[1] these regions may be shifted within wide limits to various oscillation frequencies. It is unnecessary to discuss these changes, except to state that, as before, they may be accomplished by proper manipulation of the filament current, the resistance R and all values of inductance and capacitance.

Since the oscillation frequency varies for all values of C_2 and L_2, it was desired to study this over the range used. A bridge method was employed and the auxiliary circuit was coupled loosely to the oscillator in order to minimize reaction between the two circuits. To obtain sufficient signal intensity, a four-stage amplifier and low pass wave filter were placed before the bridge.

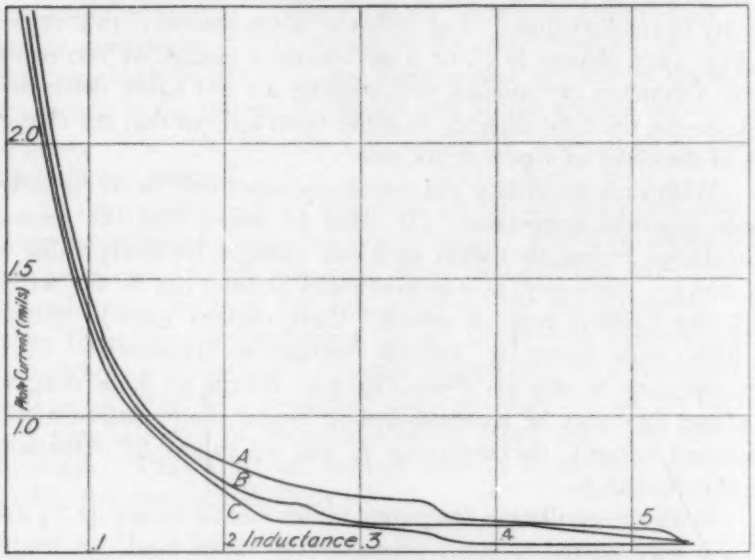
Fig. 3, showing the relation of F to C_1, shows also the effect of C_1 upon the frequency of the oscillator (curve n). It will be observed that it remains practically constant. This was expected since C_1 was made very large compared with C_2.

In Fig. 4 is shown the relation between oscillation frequency n and capacity C_2 and in Fig. 14 the relation between oscillation frequency and inductance L_2. These appear to follow the simple $n = 2\pi\sqrt{LC}$ approximation for the valve oscillator, but their main

interest is in showing a continuous variation of frequency in either case. There appears to be no unusual change in frequency in the critical regions. They also showed that there was no relation between the frequencies and the critical inductance or critical capacitance regions. However, as will be seen later, the frequency has an important bearing on the operation of the circuit.

The changes in plate current were also studied. Fig. 9 shows the plate current as a function of L_2 for different values of C_2.

FIG. 9.



Changes in plate current as inductance L_2 is varied. (L_2 in henrys.)

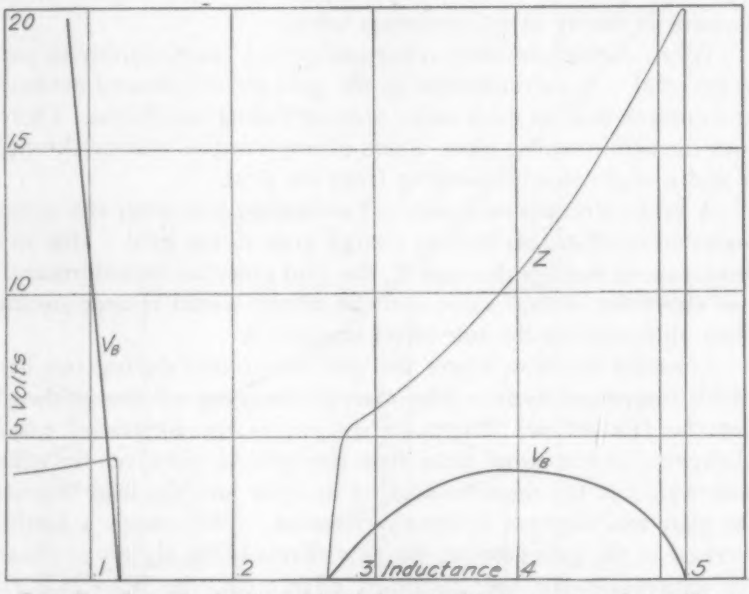
It will be observed that in the lower part of each curve there are two definite discontinuities, and that beyond a certain value of L_2 the plate current reaches approximately the same value of each curve. By comparing each curve with the corresponding curves of F against L_2, it was found that the discontinuities occurred roughly at the same values of L_2 as the critical zule frequency regions.

A similar set of curves was obtained for plate current against capacity. These curves appeared very irregular, and the various breaks did not seem to have any definite relation to the critical regions of the F–C_2 curves. Their principal value was in showing

that the plate current did not vary over a wide range as C_2 was varied over the entire range employed in the previous experiments.

By making a slight modification in the grid circuit of the oscillator another relationship was found. The grid circuit was divided, and a source of variable potential, employing a potentiostat, was inserted (Fig. 1). By this means a positive potential

FIG. 10.



Curve V_B—Curve showing the positive biasing potential necessary to apply to grid to produce steady oscillation in place of sules. (Curve Z in this and following figures is only to show the relative positions of the other curves.) (L_2 is in henrys.)

was applied to the grid and varied until the accumulated charge was neutralized and the circuit abandoned the intermittent state and oscillated normally. Below the first critical region, this positive neutralizing potential decreases very rapidly from a high value by a linear relationship (Fig. 10). It was observed that the neutralizing potential reached a zero value at the same value of L_2 as the appearance of the steady oscillation state, as was to be expected. Between the second and third regions its increase was comparatively small, and passing through a maximum value became zero again at the third critical value of L_2. Its importance will be discussed later.

DISCUSSION.

During normal oscillation the mean potential of the grid is negative with respect to the filament and the grid potential variations are induced by the impedance coupling RC_1L_1. This is the only essential variation from the simple Hartley circuit. In the circuit used the phase difference between the grid and plate potentials is but slightly less than 180°.[4] Thus when the grid is at its maximum positive value, the plate potential with respect to the filament is nearly at its minimum value.

When oscillation ceases, electrons do not cease entirely to pass to the grid. A galvanometer in the grid circuit showed evidence of a current flowing even under non-oscillating conditions. Therefore the action taking place is one of exponential leakage through R and a slight steady charging from the grid.

A grid current is necessary. For assume that after the circuit ceases to oscillate, no further charge goes to the grid. Due to a finite rate of leakage through R, the grid potential would instantly rise above the critical value and the circuit would resume oscillations, thus making the zule effect impossible.

Consider the case where the grid is positive during one-half of an impressed cycle. The rate of charging of the grid will then be $f(a \sin pt)$ where $(a \sin pt)$ is the impressed e.m.f. However, at the same time that the grid is positive, the plate potential is in the negative half of its cycle and the field between the plate and filament is thereby reduced. This causes a further increase in the grid current, the two effects being always in phase. An expression for the combined effects may be $dQ = f(E_g)\,dt$ since the actual form of the wave is determined by the dynamic grid potential-grid current characteristic of the tube.

However, at the same time that this charge is accumulating, it is also leaking off through the resistance R at some finite rate. Thus the complete equation expressing the rate of building up of charge will be:

$$\frac{dQ}{dt} = \frac{-Q}{C} \cdot \frac{1}{R} + f(E_g) \qquad (4)$$

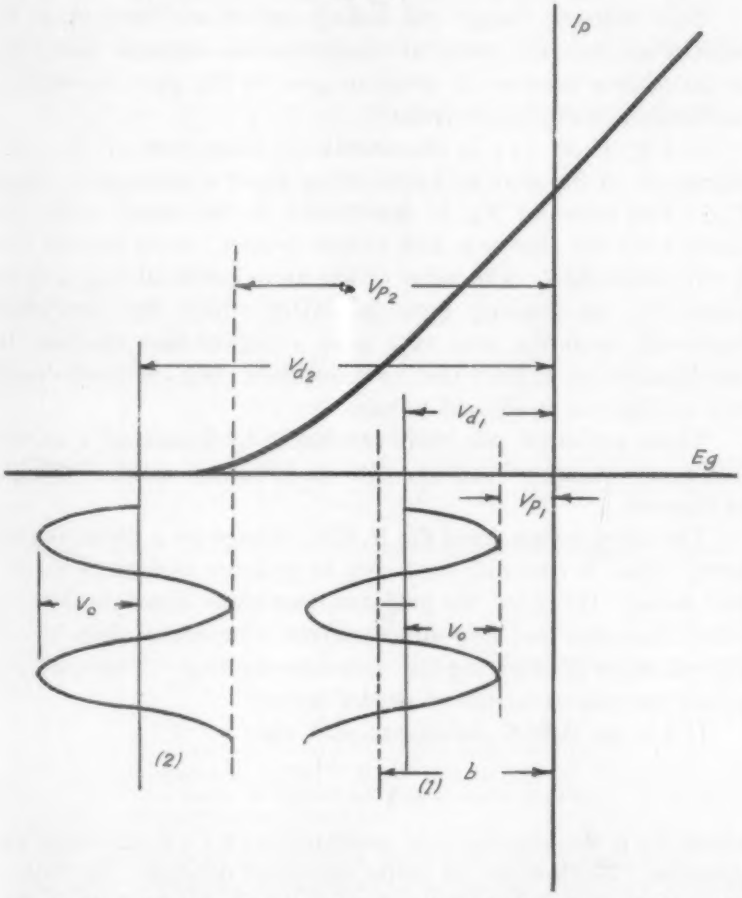
where Q is the charge on the isolated part of the grid circuit, and C is the combined capacity of $C_1 + C_2$. The first term is that due to leakage of the trapped charge through R.

The above relation holds only for the half cycle during which

[4] R. A. HEISING, *Jour. A. I. E. E.*, **29**, 365–376 (April, 1920).

the grid is positive, thus building up to a negative potential V_1. During the other half cycle the second term drops out and the only action is one of leakage, so that the mean potential of the grid falls off exponentially to some less negative value V_2. In

FIG. 11.



general $V_1 < V_2$ in order to give continued charging of the grid, in which case charging will be resumed during the third half cycle, depressing the grid to a value V_3 and so on. When the leakage equals the charging, no intermittent effect will take place.

Due to this cumulative effect, the portion of the time during which the grid is negative to the filament becomes increasingly

greater than the time during which it is positive. Thus the accumulation process itself becomes retarded as the oscillation state continues. Therefore to produce zules the following relation must hold:

$$(V_n - V_{n-1}) > (V_{n-1} - V_{n-2}) > (V_{n-2} - V_{n-3}) > \text{etc.} \quad (5)$$

This alternate charge and leakage action continues up to the point when the grid potential reaches such a negative value that an insufficient number of electrons pass to the plate to maintain oscillations in the main circuit.

In Fig. 11 let (1) be the alternating component of the e.m.f. impressed on the grid, and alternating about a mean grid voltage V_{d1}. The value of V_{d1} is determined by the steady state condition when the charge is able to leak from C_1 more rapidly than it can accumulate. The value of the mean potential V_{d2} is determined by the limiting potential, after which the oscillations impressed upon the grid vary over a region that overlaps the characteristic so slightly that an insufficient plate current to maintain oscillations is allowed to pass.

These potentials are easily obtainable by means of a vacuum tube peak voltmeter [5] and idiostatic electrometer across from grid to filament.

The electrometer gives the R.M.S. voltage on a direct reading scale. Thus it could be used only to measure variations about a zero value. However, the grid oscillates about some steady value other than zero and this direct current component must be considered when interpreting the voltmeter reading. This fact simplified the measurements as shown below.

If b is the R.M.S. voltage as read, then

$$b = \sqrt{V_d^2 + \frac{V_0^2}{2}} \quad (6)$$

where V_0 is the amplitude of oscillation and V_d is the mean grid potential. Neither can be easily measured directly. In order to work over a more sensitive part of the scale for low values of b, a battery of voltage E was added in series with the voltmeter so that

$$b = \sqrt{(V_d + E)^2 + \frac{V_0^2}{2}}. \quad (7)$$

[5] H. J. VAN DER BIJL, "Thermionic Vacuum Tube," p. 367 (1920).

The peak voltage V_p as measured gives

$$V_p = V_d - V_0 \tag{8}$$

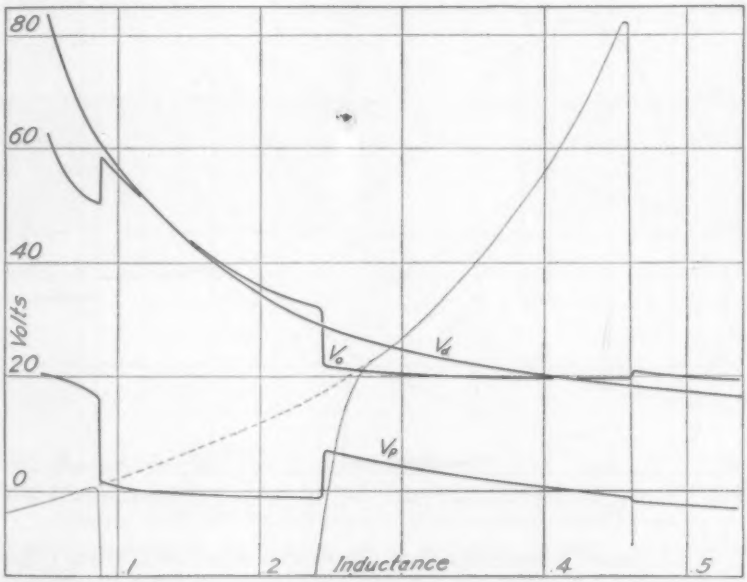
Solving these two expressions simultaneously gives

$$V_d = \frac{2E + V_p}{3} - \frac{1}{3}\sqrt{4E\,V_p + 6b^2 - 2E^2 - 2V_p^2} \tag{9}$$

where E_p was zero and dropped out when the electrometer was used alone.

Thus from V_p, V_d and V_0 all desired information regarding

FIG. 12.



Variations with inductance L_2 of: (1) Mean grid potential, V_d. (2) Amplitude of oscillation, V_0. (3) Peak voltage of oscillations with respect to the filament, V_p. (L_2 in henrys.) Note the extrapolation across the zule curve gap.

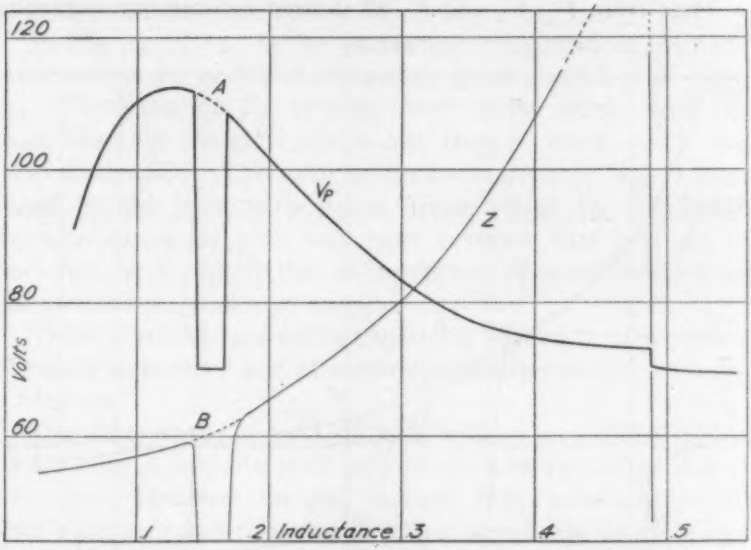
the mean position of oscillations, values of zule cut-offs, etc., may be obtained. The depression of the mean grid potential does not affect the amplitude of oscillation except close to the cut-off regions. Thus the difference between the peak voltage and amplitude during zules would give the mean grid potential where the amplitude was obtained after raising the grid potential until steady oscillation occurred.

Fig. 12 shows curves for V_p, V_d and V_0 plotted against L_2.

It will be noticed that V_d gives a smooth curve, while the amplitude V_0 is discontinuous at the critical zule regions.

Peak voltages across the variable inductance L_2 also show a discontinuity at the zule region limits, where the peaks fall to a low and seemingly constant value which was about two volts above that of the plate battery (Fig. 13). This low value of V_p was the same in the second region of normal oscillation. When

FIG. 13.



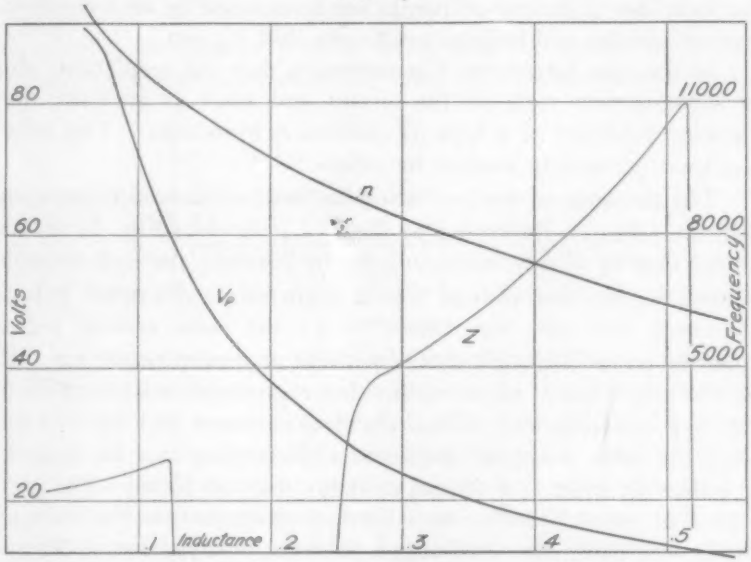
Peak voltage V_p measured between O and D (Fig. 1). Curve V_p is continuous at A when curve Z is made continuous at B. Plate battery, 68 volts. (L_2 in henrys.)

C_3 is increased sufficiently that the first normal oscillation region vanishes, no discontinuity in V_p then occurs. Similar curves (Fig. 14) taken across L_1 showed a continuous change in V_p regardless of the existence of normal oscillation regions. Thus it appears that the entire oscillating circuit is not necessarily an agent in the zule effect. This part of the study was carried no further.

A biasing potential (positive or negative), inserted in the circuit next to the grid, serves to bring out several factors concerning the effect of the grid depression. It is seen that the state of depression of the grid potential is the controlling factor of the zule or steady state.

The biasing potential does not in any way alter the mean voltage about which the alternating component of the e.m.f. varies. At any one value of L_2 and C_2, the peak voltage V_p and the R.M.S. voltage V_M remained constant for any value, positive or negative of the biasing potential V_B. As shown before, the mean oscillating e.m.f. is determined by V_P and V_M and therefore it is shown that this remains constant. For example, in a

FIG. 14.



Curve V_p—Peak voltage across L_1. Curve N—Oscillation frequency variation, corresponding to inductance L_2 changes for curves Z and V_p. (L_2 in henrys.)

region of normal oscillation let a negative biasing potential be applied. Down to a certain value of V_B, steady oscillation persists. Then it is found that the zule state is again entered when the biasing potential is made less than a definite critical value. The zule frequency changes with V_B down to a fixed value of V_B, at which all oscillation ceases. This cut-off value of V_B is constant for all values of L_2 and C_2 at about 15 volts. Over all of the changes above, V_P and V_M did not vary, until oscillation stopped entirely, showing that the impressed e.m.f. was unaffected.

Thus the application of a known V_B can produce exactly similar effects to those of the resistance R and capacitance C, which cause a charge accumulation on the grid.

A similar effect is found in the zule regions when a positive biasing potential is applied. Upon increasing V_B the zules finally cease and steady oscillation occurs. The critical value of V_B changes with L_2 as shown in Fig. 10. At the critical cut-off regions, the biasing potential necessary to transform the oscillations from normal to intermittent or *vice versa* is of necessity equal to zero. Also that this value $V_B = 0$ is the necessary and sufficient condition to fix the critical cut-off regions. Therefore the locations of the cut-off points are determined by such combinations of charge and leakage conditions that $V_B = 0$.

In the zule formation it is necessary that the oscillations stop at some certain state of the circuit and start at another, thus showing evidence of a type of oscillation hysteresis. This effect has been previously studied by others.[6, 7, 8]

The presence of such a factor has been evidenced experimentally as follows: Referring to the F–L_2 curves (Fig. 7) it was found that by slowly increasing L_2 by rotating the inductometer secondary, the first critical region occurred as discussed before. However, for very low values of C_2 the same critical region could be passed through slowly without any zules occurring. If, on the other hand, when within this region the inductometer be changed suddenly, the normal oscillation ceases and zules occur. Once the zules are established, the whole region may be explored in either direction. A second evidence may be found within any region of normal oscillation, where a sudden shift in the inductometer will cause the oscillations to cease entirely for a definite time, but one of varying length according to the magnitude of the shift. The same may be accomplished by means of a sudden change in the variable condenser C_2. A third evidence occurs within these same regions when a very slight jar of the vacuum tube or any part of the apparatus would cause the same effect. Response to loud sounds of certain pitches also interrupted the oscillations. A fourth evidence was pointed out in a recent paper by the writer, in discussing the Colpitts circuit used as an intermittent oscillator.[1] Here the critical regions varied according to the direction and manner of approach, showing a lag effect.

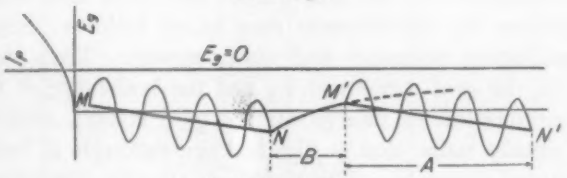
Other definite examples of hysteresis of oscillations were

[6] APPLETON and VAN DER POL, *P. M.*, **43**, 179 (1922).
[7] VAN DER POL, *P. M.*, **43**, 700 (1922).
[8] W. ALBERSHEIM, *Archiv. f. Electrot.*, **14**, 23 (1925).

observed to be dependent upon the state of the grid potential. For example, when a negative potential V_B is applied to the grid, oscillation is entirely cut off at some value V_0 of the biasing potential, and silence results. Then V_B must be returned to a value V_1 several volts more positive before oscillations are resumed. Thus $V_1 > V_0$. For various values of L_2 and C_2, V_0 remained fixed at about 13.5 or 14 volts, but V_1 varied. This condition was for $R = 0$.

Consider the exaggerated oscillation diagram in Fig. 15. Due to the cumulative process mentioned before the mean grid potential will decrease along MN until the oscillations overlap the

FIG. 15.



Oscillation diagram.

dynamic characteristic insufficiently. Actually this occurs in steps until oscillation stops. From this stage the grid potential increases exponentially to some point M' above the dynamic cut-off, where a transient e.m.f. is capable of being increased sufficiently for maintained oscillations to result. From this point the cycle is repeated, A representing a zule cycle. From mean and peak voltage considerations, it was found that M' remained nearly constant (−13.5 volts) for all circuit conditions, was greater than the cut-off voltage (−15.0 volts), and less than zero grid potential. The length of the interval B is determined by several such factors as the time constant of the grid circuit, the grid current, etc. After M', the time necessary for the oscillations to build up to their maximum value is negligible compared with the length of a zule. N corresponds to V_{p2} and M' to one value of V_{d1} in Fig. 11.

It is significant that for any changes in V_B, while zules are occurring, there is no appreciable change in the duration of each zule. There is a variation as L_2 changes when $V_B = 0$. If the application of V_B actually lowered the mean impressed e.m.f., the rate of charge accumulation would decrease and the zule become longer.

Also the critical value to which the grid may be depressed before all oscillations are cut off is fixed at some value, say V_0. The critical grid potential value at which oscillations may begin again is fixed at some value, say V_1. Therefore the time of leakage should always be the same for fixed values of L, R, and C. However, this time varies as V_B is changed, all else remaining constant. The potential V_B serves only to add to or detract from the potential of C_1 and so changes the time of leakage. It was found that the zule frequency F becomes less as V_B becomes more negative. The interval NM' (Fig. 15) increased in length while the zule length MN remained unchanged as V_B was thus decreased.

An explanation of the starting of the zules and stoppage of the oscillations by disturbances may be as follows: Suppose the circuit oscillating normally and continuously. Then due to the presence of the grid condenser C_1 and the resistance R there is a slight accumulation of charge on the grid circuit, which is held at some steady value due to the leakage through R being equal to the rate of increase. The circuit is thereby operating nearer to its critical cut-off state than if C_1 and R were absent. If now L_2 be suddenly changed there is a transient e.m.f. set up in the circuit by induction. This causes a large increase in the positive part of the grid cycle and sufficient charge is accumulated during that interval to cut off the oscillations. This extra charge leaking through R requires a finite time to escape and thus bring the circuit to its critical starting state again. Thus, there will be a definite stop in the oscillations, as was observed. Being no further disturbance, there will be only one break, for the circuit will have returned to its equilibrium state. The same effect will occur within the critical regions, but here the circuit after its first interruption will not fall to the steady state value again since the zule effect will commence at some higher value of the charge in that circuit.

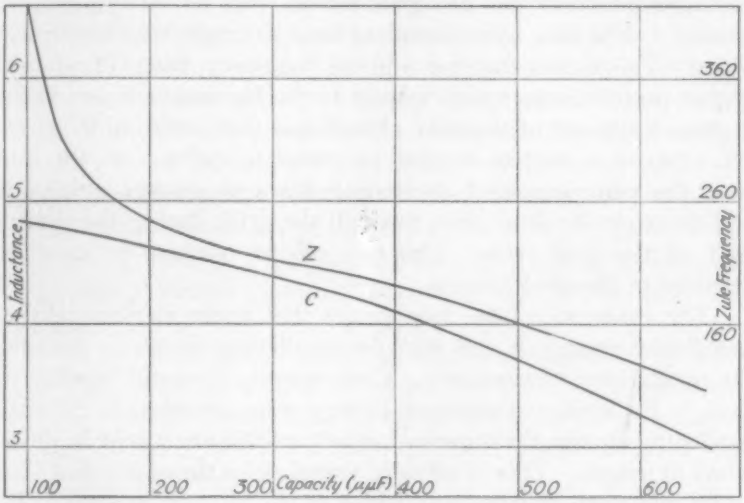
It was observed that as R increased the actual length of the zule became shorter, *i.e.*, the time for the grid potential to fall from M to N became less (Fig. 15). Correspondingly the interval NM' becomes longer. Among other factors, the length of this interval depends upon the time constant of the circuit. From equation (4):

$$t = RC \log_e \frac{Q_0}{Q} \tag{10}$$

where Q_0 is the charge on C_1 when t is measured zero. Neglecting other factors, this gives the time of leakage during silence. For fixed circuit conditions Q is constant and t is proportional to R. Thus the length of the silent interval will increase with R, thereby causing a shortening of the zules.

The rate of charge accumulation on the grid varies with the oscillation frequency and amplitude. Experimental curves for

FIG. 16.



Curve Z—Zule frequency, at constant oscillation frequency N. Curve C—Relation between L_2 and C_2 to maintain N constant.

frequency change with L_2 showed no discontinuities over the break regions. By maintaining the oscillation frequency (n) constant by a double adjustment of L_2 and C_2, its qualitative effect on the zule frequency may be obtained (Fig. 16). Curve C shows the variation of L_2 and C_2 necessary to maintain n constant, and curve Z above shows the corresponding variation in zule frequency. Over a wide range of L_2 and C_2 there is no marked change in F, nor evidence of any critical regions. It is only for the low values of C_2 that the zule frequency F changes markedly, and here it increases very rapidly and suddenly to values too high to count.

The zules become so rapid that the tone is harsh or throbbing, and finally the stage is reached where the natural tone of the oscillator only is heard.

As the frequency n increases, the grid is positive with respect to the filament for a greater part of a given time. Thus the leakage through R becomes less per half cycle and the charging of $C_1 + C_2$ greater, so that the net result is one of an increase in the charging rate of the grid circuit to its critical value. This will mean that the zules become shorter, since the charge will reach the critical value in a shorter length of time.

If the amplitude of oscillation in the main circuit is increased, the induced e.m.f. in the grid circuit will be correspondingly greater. The two were found to bear a simple relation to each other. This means that for a given frequency, the grid attaining higher positive values with respect to the filament will accumulate a greater amount of negative charge and thus build up to its cut-off value in a smaller number of complete cycles. At the same time the plate potential alternating through greater amplitudes will decrease the stray field through the grid, during the positive half of the grid cycle. The two effects combine to cause an increase in the grid current.

The existence of the zule means that under those conditions insufficient energy is fed into the oscillating circuit to maintain the oscillations continuously. Consequently it would be expected that, if for some reason more energy were absorbed in the main oscillating circuit, the region of steady oscillation would be diminished in length. This is actually found to be the case when some additional pure resistance is added in L_1, L_2, C_1 and C_2. The effect of increasing this resistance is to cause the first and second critical regions (Fig. 7) to approach each other and finally merge. Throughout the study of the resistance in the oscillating circuit was fixed at about 30 ohms.

In conclusion, I wish to express my appreciation to Profs. E. Merritt and C. C. Murdock for their interest in this investigation and for their helpful suggestions.

Industrial Alcohol Manufacturers Establish Fellowship.—The Industrial Alcohol Manufacturers' Association has founded an Industrial Fellowship in Mellon Institute of Industrial Research of the University of Pittsburgh, for the purpose of studying denaturants, in order to find an ideal one, if possible. This would be a substance possessing such properties and physiological action that it would render ethyl alcohol undrinkable, but could not be separated in any way from the alcohol and would not injure it for technical uses.

THE USE OF MODELS IN THE SOLUTION OF INDETERMINATE STRUCTURES.*

BY

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FURTHER knowledge of the action of indeterminate structures will be extended primarily by observation and experiment. Structural mathematics, based upon the simple laws of equilibrium, stress-strain proportionality, and the conservation of energy, has developed into a very complicated system. Mathematical analysis is demonstrated by the analysts themselves to be an inadequate practical means for the solution of many problems, as evidenced by the difficulties inherent in the methods of "Least Work," "Slope Deflections," "Ellipse of Elasticity," "Elastic Weights," "Conjugate Beams," and "Theorems of Three and Four Moments." The theoretical solutions commonly employed have departed far from any evident relationship to the actual structure. It appears imperative that a return be made to experimental methods whereby nature may be compelled to serve the structural engineer in the solution of many practical problems in the field of indeterminate structures.

To circumvent the laborious mathematical solutions, a practical method of solving many types of indeterminate structures by the aid of elastic models has been developed. It is based upon the same fundamental principles as lie at the basis of many mathematical methods, in particular, Maxwell's theorem of reciprocal deflections. The essential difference between the mathematical and mechanical methods of solution is that the laborious calculation of required deflections is replaced by their direct measurement. A particular advantage of the mechanical method is that it completely avoids the use of integral calculus and the solution of groups of simultaneous equations, for each indeterminate quantity is directly expressed as a function of a known load and two measurable deflections. Furthermore, since the solution by use of models allows all stress components to be determined from measured deflections, there remains for checking purposes the

* Presented at a meeting held Thursday, October 29, 1925.

three unused equations of statical equilibrium. For this reason the mechanical method of solution is spoken of as self-checking. Since a model automatically takes into account the effect of thrust and shear deformations, varying moments of inertia, effect of brackets, and peculiar distribution of stresses around corners of frames, the solution obtained from a model is probably nearer the truth than the solutions obtained by approximate theories.

The economic advantage of the mechanical method arises from the fact that difficult practical problems of an indeterminate character may be solved accurately with a model more speedily than by calculation, and the clerical work incident to the mechanical solution may be done by those who have had no theoretical training in the special subject of indeterminate structures. Furthermore, an engineer or architect who employs models in designing secures for himself greater freedom in the choice of unusual structural forms, which may be either more economical or more artistic.

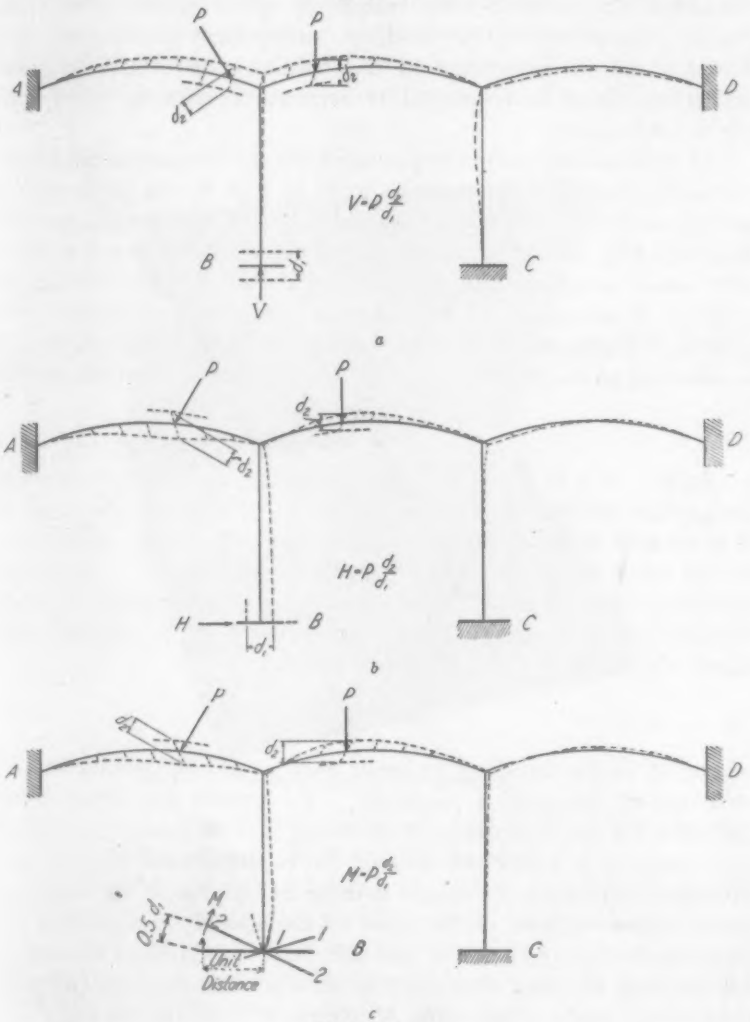
The underlying principle of the solution of structures by the use of models will be clear from a consideration of Fig. 1, *a*, *b*, *c*. The line diagram in each lettered figure represents the centre line of a model of an indeterminate structure. The reaction components—vertical, horizontal, and rotative—due to any assumed load P, are to be found experimentally. It should be observed that in the mechanical solution no actual load is applied to the model at the point of assumed loading, for the process consists merely in the introduction of a known displacement at the section of desired stress and the measurement of the corresponding displacement at the point of assumed loading. Let us deal first with the vertical component of the reaction at support B, Fig. 1*a*, corresponding to any assumed load P on the structure. Suppose the other supports A, C, D to be held fixed. Let a very small finite vertical displacement d_1 be produced in the model at B without permitting rotation or horizontal displacement of this support. The corresponding component of displacement d_2 at the load-point P in the direction of P is observed with a microscope. It follows from elastic theory that the vertical component V of the reaction at B is given by the equation

$$V = P\left(\frac{d_2}{d_1}\right).$$

It appears, therefore, that the solution with an elastic model is

remarkably simple, as soon as means are provided for the easy manufacture of models and for the accurate introduction and

FIG. 1.



Triple arches.

measurement of the necessary deflections. Attention is directed particularly to the necessity of employing small deflections in the solution of indeterminate structures with the aid of elastic models,

for the ratio of deflections is theoretically and practically correct only when the model is deformed a small microscopically measurable distance from its geometric shape; but if large deflections are employed, the method very frequently gives results which are grossly inaccurate. The leading authorities in Europe and America are in agreement in the opinion that relatively small deflections must be employed if accurate results in every case are to be expected.

If it is desired to find experimentally the horizontal and rotative components of the reaction at B in Fig. 1, the procedure is analogous to that described for obtaining the vertical component. Refer to Fig. 1*b*. Let the support B be displaced horizontally a very small measurable distance, d_1, without allowing vertical or rotative displacement of this support. The corresponding component of displacement d_2 at the load-point P in the direction of P is observed with a microscope. It follows from elastic theory that

$$H = P\left(\frac{d_2}{d_1}\right).$$

Again, if it is desired to determine the rotative, or moment, component of the reaction at support B, Fig. 1*c*, the support B is rotated through a very small measurable angle, determined by the value d_1, at radius unity, as shown in Fig. 1*c*. The corresponding component of displacement d_2 at the load-point P in the direction of P is observed with a microscope. It follows from elastic theory that

$$M = P \cdot \frac{d_2}{d_1},$$

where M is the bending moment that would be produced in a structure of the scale of the model. To convert this moment into the value for the full-sized construction, it is necessary to multiply by a quantity n, where the scale of the model is such that one unit of length of the model equals n units of length of the full-sized construction. Thus, if the scale of the model is such that *one inch* equals *three feet* and if the unit load is expressed in pounds, the bending moment expressed in foot-pounds for the full-sized structure is equal to the value M, obtained from the model, multiplied by the quantity which, in this case, equals *three*. The values of V and H, however, are not subject to correction for the scale of the model.

The direction, sense, or sign, of any stress component, may

be noted by observation of the deformation of the model. The microscopes employed in measuring deflections are optically inverting, so that the image in the microscope moves in an opposite direction from the observed load-point. Accordingly, the following practical general rule for determining the sense of any reaction or stress component has been formulated: If the image of the load-point in the microscope moves in the direction of the

FIG. 2.

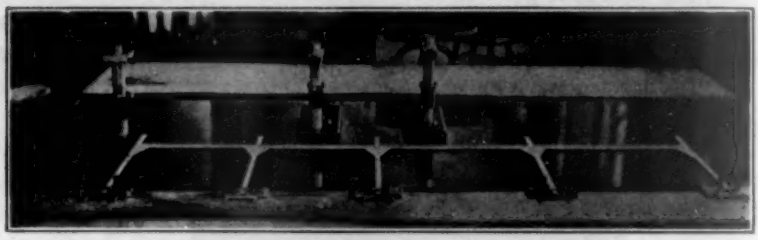
Standard box of deformeter gauges.

assumed load, the reaction component acts in the same direction as the corresponding displacement of the support.

By observing simultaneously with several microscopes the displacements at various points of the model corresponding to predetermined displacements at sections of unknown stress, influence lines for reaction and stress components may rapidly be obtained. Then by employing these influence lines in a manner well known to structural engineers, it is possible to compute readily the effect of any manner of concentrated or distributed loading, and also to determine where live loads should be placed to produce maximum stresses.

The deformeter apparatus employed in connection with elastic models is illustrated in Figs. 2, 3 and 4. It consists of very precise means for producing known, but very small, displacements

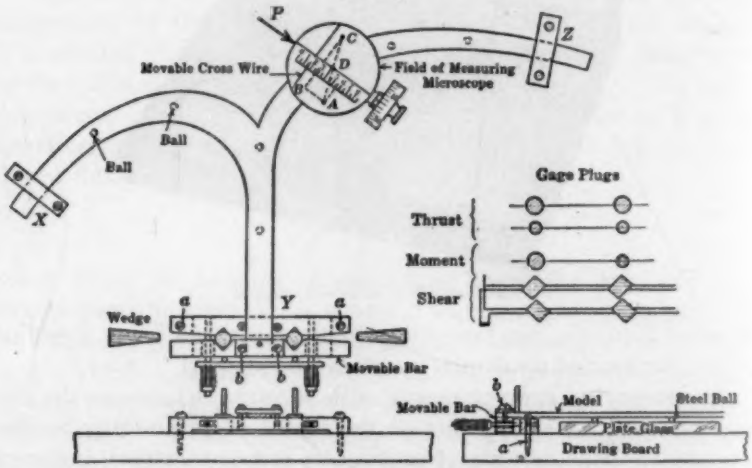
FIG. 3.



Illinois Central R. R. model.

at sections where stress is sought, and optical means for measuring the deflections of the model at assumed load-points. In Fig. 2 is shown a standard set of deformeter gauges. In Fig. 3 is shown a model of an indeterminate frame connected to the defor-

FIG. 4.

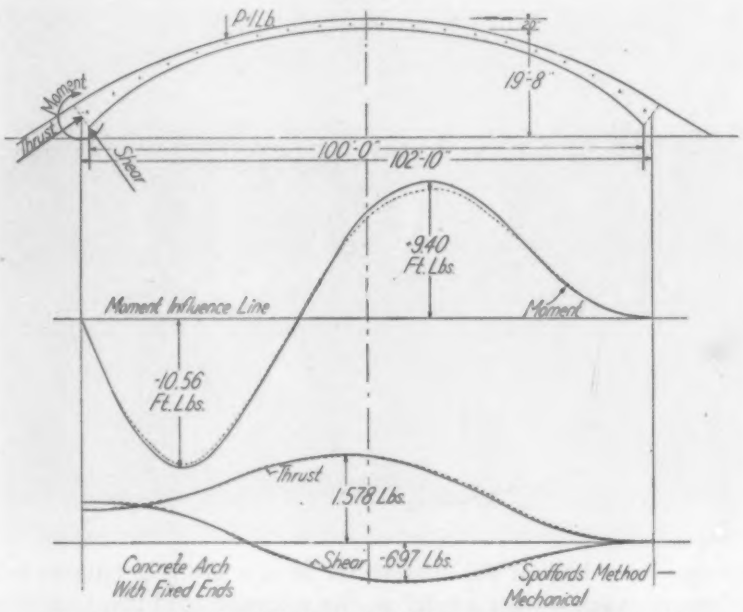


Detail drawing of deformeter apparatus.

meter gauges and in position for deformation readings. The manner of introducing and measuring displacements will be clear from the following description given in connection with Fig. 4. In this figure is shown a model connected to a drawing board by a deformeter gauge and two clamps. It is desired to find experi-

mentally the components of the reaction at the foot of the elastic column due to any assumed load P on the structure. The deformeter gauge consists of two parallel steel bars, with pairs of opposing V-notches, held together by coil springs so as to allow a small relative motion between the bars. Very precise gauge plugs of accurately specified sizes (tolerance plus or minus 0.0002 inch) are provided for introduction between the gauge bars, for the purpose of producing predetermined amounts of thrust, shear,

FIG. 5.

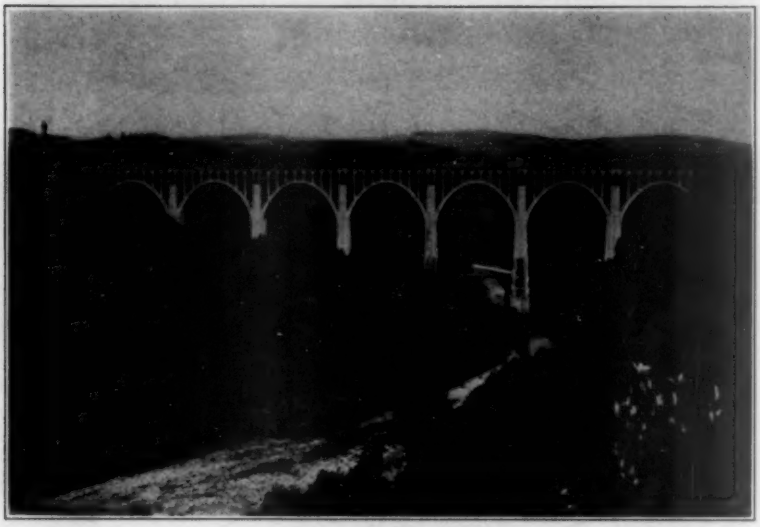


Comparison of experimental and calculated influence lines for a concrete arch.

and rotative displacement. The thrust and shear displacements employed in practice equal 0.0500 inch. The so-called " fixed bar " of the gauge is secured to the drawing-board by screws, marked *aa*. By means of a clamping plate, the model is attached to the movable bar of the gauge, if the support is assumed fixed; or by a needle point, if the support is assumed hinged. For the unstrained position of the model, two " normal " gauge plugs remain in the two pairs of opposing V-notches of the gauge. The model is supported in a horizontal plane by steel balls rolling on glass, so that no friction will restrain the movements of the model. A filar

micrometer microscope is set up over the assumed point of applied load, and the fixed cross-hair of the micrometer, which is parallel to the micrometer screw, is oriented parallel to the direction of the assumed load by sighting at a scribe mark on the model. (Refer to Fig. 4.) Suppose the vertical thrust component of the reaction at Y is sought. The "normal" plugs are removed from the gauge at this support, and a pair of smaller thrust plugs are inserted, so causing a vertical displacement of the support. The

FIG. 6.



Grand Fey Viaduct.

moving cross-hair of the micrometer is now brought tangent to a reference mark on the model at the assumed load-point, and an initial reading of the micrometer is taken. The small thrust plugs are now removed and larger thrust plugs are inserted in the deformeter gauge. Thus is produced a predetermined amount of known vertical displacement at the support and a definite deformation of the elastic model. The reference mark will move across the field of view in some diagonal direction AC. The moving cross-hair of the micrometer is again brought tangent to the reference mark and a second reading of the micrometer is taken. The difference between the two micrometer readings will be the component AB of the motion AC of the reference mark, this component being measured in the direction of the assumed load.

The V component of the desired reaction now equals the applied load multiplied by the ratio of two known deflections, namely, AB and the gauge displacement. In a similar manner, as indicated earlier in Fig. 1*b*, *c*, the other two components of this reaction may be found.

The models used in connection with deformeter gauges are made of celluloid or fine quality cardboard. They are usually of constant thickness. The model is not necessarily a small-scale

FIG. 7.

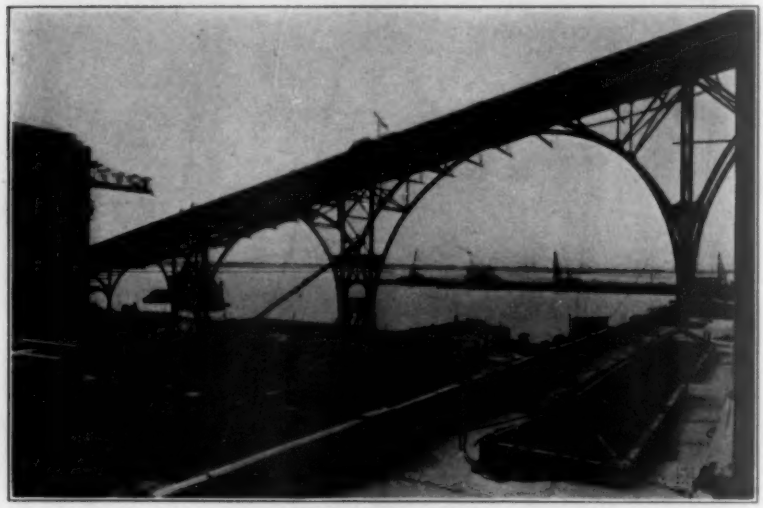
Grand Fey model.

reproduction of the actual structure, but its members are given the same proportions of stiffness as those of the actual structure by making the widths of the model members proportional to the cube roots of the moments of inertia of the actual cross-sections. It will be noted that the coefficient of elasticity both of the model and of the actual structure may be disregarded, for the ratio of deflections is independent of this coefficient. Cardboard for models has a thickness of about one-twentieth inch, and may be cut neatly by repeated strokes of a sharp thin-edged knife. Celluloid for models is used in thickness 0.080 inch to 0.100 inch, and may be obtained in the stock size 20 inches by 50 inches. Cement for welding together pieces of celluloid is also available. The

outline of a model may be scribed directly on the celluloid, and the cutting may be rapidly and accurately done with a standard type of portable jig-saw, taking power from an electric light socket. The motor-driven jig-saw is so efficient that only a few minutes are required for cutting simple models from either celluloid or cardboard. Well-seasoned celluloid is preferred because of its durability, but excellent results may be obtained with ten-ply cardboard of fine quality.

The accuracy of analysis by elastic models is very satisfactory,

FIG. 8.



Arches for Richmond Station.

as has been proved repeatedly by experiment and by calculation. In Fig. 5 is shown a comparison of influence lines obtained by a model and by the usual theory for a concrete arch with fixed ends. This test was made at the Massachusetts Institute of Technology under the direction of Prof. Hale Sutherland, and the report about the experiment expresses satisfaction with the results obtained from the model. Many other trial tests in which the results of accepted theory have been compared with the results from models have been made in university laboratories and designing offices, and the consensus of opinion is that the results from the model are very close to the truth. For important results the experimental error does not exceed 1 per cent.

The deformeter gauge method may also be used to solve structures which are internally indeterminate. The gauge in this instance is attached to the intermediate cut section of the structure where the thrust, shear, and moment components of internal stress are sought. The gauge is mounted upon a frictionless bearing, so that it may move freely with the model structure as gauge plugs of various sizes are introduced between the gauge bars. This frictionless bearing may be made of two glass plates, such as used for lantern slides, with small steel bearing balls between them. The same simple equations as express the relation between assumed load and external reaction components also relate the assumed load to the thrust, shear, and moment components of internal stress. The method has thus been extended to the practical solution of many problems involving internal indeterminancy. A notable example of this manner of solution is in connection with the recently completed Grand Fey Viaduct near Fribourg, Switzerland, shown in Fig. 6. The celluloid model and deformeter gauge apparatus used for the analysis of this structure are shown in Fig. 7. Mr. Adolph Bühler, bridge engineer for the National Swiss Railways, reports that the working of the superstructure of this bridge with the arch itself greatly modifies the structural behavior of the entire construction, to such an extent that the classical theories of arch action are in this case greatly in error. In the design of this great double-track railway bridge, the results obtained from a celluloid model were followed with confidence.

The method may be applied to the design of structures of other materials than reinforced concrete. In Fig. 8 is shown an unsymmetrical arch system designed to support the coal conveyors of the new Richmond Station in Philadelphia. The design of this arch system was made from a study of the deflections of a celluloid model made under the direction of Mr. Frank Kneas, structural engineer for John T. Windrim, Consulting Architect. Other examples of practical constructions in steel and reinforced concrete designed from models are now appearing in various parts of the world. The mechanical solution of the steel frames for supporting signals and electrification over the tracks of the Illinois Central Railroad, Chicago, and the design of frame bridges of reinforced concrete with the aid of elastic models, by Mr. Arthur G. Hayden, designing engineer of the Westchester

County Park Commission, are noteworthy early applications of the method. The structures to which this method may be applied are of numerous types, but in general all forms of two dimensional indeterminate construction may be analyzed practically by model studies. In such a classification may be named the following: Continuous beams with variable moments of inertia; portals and building frames; tunnel and sewer sections; large penstocks; arches of various types, including high arches with flying buttresses; machine and locomotive frames; indeterminate frames for aeroplanes and dirigibles; special designs for resisting earthquakes; spoked flywheels of great diameter; continuous frames for subway construction; Viereendel girders; multiple arch frames for industrial buildings, etc. This list will undoubtedly be extended as new applications for the method are discovered by practising engineers or as new forms of structural framing are created.

Chlorpicrin as an Insecticide.—Chlorpicrin or trichloronitromethane has been used in chemical warfare as a moderately toxic, somewhat lachrymatory, "vomiting gas." A. L. STRAND (University of Minnesota, Agric. Extension Div., *Special Bulletin No. 102*, 1926, 1–19) recommends the use of chlorpicrin as an insecticide for mill and household insects, and describes methods for its use in the fumigation of flour and cereal mills, upholstered furniture, and dwelling houses. The chlorpicrin is mixed with an equal volume of carbon tetrachloride and applied from an atomizing apparatus. The amount of chlorpicrin required per 1000 cubic feet of space is 1.25 pounds for dwellings, 2 pounds when furniture is treated, and 5 pounds for milling machinery. The period of exposure to the vapor should be six to twelve hours. J. S. H.

Food Laws of Pennsylvania.—The revised Law Bulletin (Penna. Dep't of Agric., *General Bulletin No. 419*, 1926, 91 pages) contains the laws of Pennsylvania concerning foods; butter; renovated butter; carbonated beverages and still drinks; cheese; coffee and chicory; cold storage; fresh eggs; eggs unfit for food; fresh meat, poultry, game and fish; fruit syrup; ice cream; imitation dairy products; lard; milk containers; milk and cream; filled milk; milk testing; non-alcoholic drinks; oleomargarine; oysters; sausage; vinegar; and bottling establishments. The rules and regulations of the Department for the enforcement of the food and cold storage acts are also given. The value of the Bulletin is increased by a digest of court decisions on the food laws. J. S. H.

PROPAGATION OF DETONATION ACROSS AN AIR-GAP BETWEEN TWO CARTRIDGES OF EXPLOSIVE.

BY

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ONE of the important physical characteristics of a mining explosive is its sensitiveness to detonation by influence. Although this property has been studied by a number of investigators, notably Berthelot,[1] Munroe,[2] Dautriche,[3] Comey,[4] and Laffitte,[5] further quantitative data as to the behavior of this phenomenon are needed.

During their experimental work on photography of flames from explosives [6] and a photographic method of determining the rate of detonation of explosives,[7] the present writers had observed a luminous phenomenon issuing from the mouth of a cannon in which a charge of explosive had been fired, and also in an air space between two cartridges of explosive confined in a glass tube. This phenomenon, which in the case of the cannon shots is usually called a "flame" and believed to consist of reacting gases and solid particles raised to incandescence, is often propagated at a rate considerably greater than the rate of detonation of the explosive. Laffitte,[5] in discussing photographs of the detonation of explosives contained in small glass tubes, has expressed the opinion that the "shock wave" sent out by the explosive

[1] BERTHELOT, M., "Explosives and Their Power," English translation, p. 75, John Murray, London, 1892.

[2] MUNROE, CHARLES E., *J. Am. Chem. Soc.*, **15**, 10–18 (1893).

[3] DAUTRICHE, H., *Compt. Rend.*, **144**, 1030 (1907).

[4] COMEY, A. M., *7th Int. Cong. Appl. Chem.*, London (1909), Sec. III b, p. 28.

[5] LAFFITTE, P., *Compt. Rend.*, **178**, 1277–1279 (1924); *Ann. des Phys.*, **4**, 587–694 (1925).

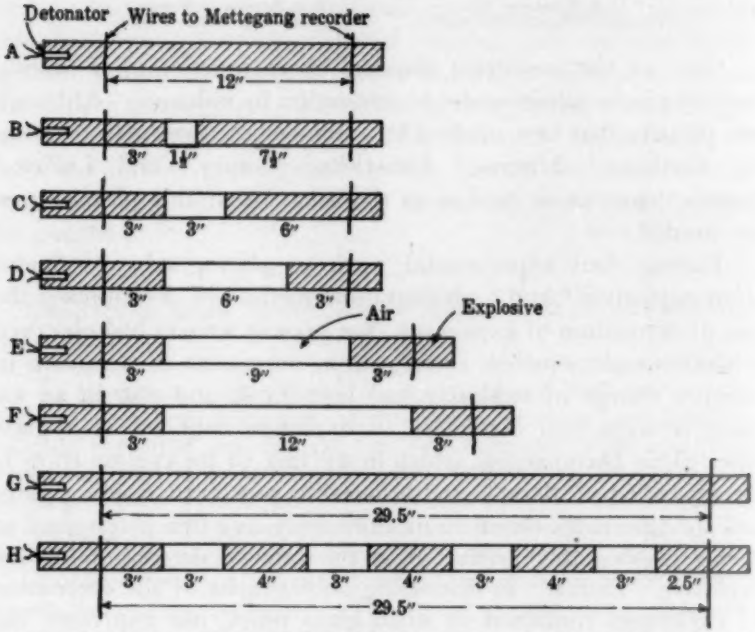
[6] PERROTT, G. ST. J., *Amer. Inst. Min. and Met. Engineers*, October meeting, 1926.

[7] PERROTT, G. ST. J., and GAWTHROP, D. B., JOUR. FRANK. INST., January, 1927, p. 103.

compresses the air in the tube to such an extent as to make it incandescent.

This paper describes a study of the velocity of propagation of detonation across an air-gap between two cartridges of dynamite. The cartridges were 1¼ inches in diameter by 8 inches long, which is the size commonly used in many mining operations. In part of the experiments the cartridges were wrapped

FIG. 1.



Detonation across an air-gap. Method of arranging charges for determination of rate of detonation by Mettegang recorder.

in Manila paper with air-gaps of varying length between them while in other experiments the explosive was contained in glass tubes. The experimental work consisted of measurement by Mettegang recorder and by the photographic method.

MEASUREMENT BY METTEGANG RECORDER.

The Mettegang recorder makes the records on a rapidly revolving smoked drum, of sparks produced by breaking of fine wires carrying current which are threaded through the explosive at known distances apart. In the procedure finally adopted, two

cartridges of explosive 1¼ inches in diameter and 7 inches long were rolled in two thicknesses of Manila paper with an air-gap between them (Fig. 1). The crimped paper had been cut off from the adjacent side of the cartridges so that the bare explosive mixture was exposed on each side of the air-gap. The length of the air-gap was varied from 1½ inches up to the distance at which detonation failed to take place in the second cartridge. It had been found from previous tests that the wires must both be threaded through the explosive. Erratic results were obtained if either or both wires were placed in the air-gap. Hence, the

TABLE I.

Properties of Explosives Used in Experiments.

Explosives.	1*a*	1*b*	2*a*	2*b*	3*a*	3*b*	4*a*	40 Per Cent. Dynamite.
Chemical analysis, per cent.: Moisture	0.5	0.5	0.4	0.4	0.5	0.5	0.6	0.8
Nitroglycerin and nitropolyglycerin	10.0		9.4		9.5		9.9	39.2
Nitroglycerin and ethylene glycol dinitrate		10.1		9.5		9.0		
Ammonium nitrate	76.4	75.9	77.9	77.8	71.0	70.9	69.9	
Sodium nitrate	2.9	3.1	2.6	3.0	....	....	....	44.1
Sodium chloride	....	....	....	....	9.3	10.1	9.6	
Calcium carbonate	0.7	0.7	0.4	0.4	0.4	0.4	0.7	1.2
Carbonaceous combustible material	9.5	9.7	9.3	8.9	9.3	9.1	9.3	14.7
Apparent density, grams per c.c.	1.00	1.01	0.80	0.80	0.96	0.97	1.01	1.34
Rate of detonation, metres per second	3480	3480	1670	1790	1740	1750	2820	4840

method indicated in Fig. 1 was employed and all original data include the velocity of propagation over a certain length of explosive and a certain length of air-gap. By making use of the determined value for the rate of detonation of the explosive, the rate of propagation of the disturbance across the air-gap can be calculated. The distance over which the rate was measured was not less than 12 inches. The length of the initiating end of the charge was the same in all cases.

The explosives used were a 40 per cent. straight nitroglycerin dynamite and seven explosives of the ammonium nitrate-nitroglycerin type. Four of the latter (designated by *a* in Table I) contained nitroglycerin and nitropolyglycerin, and of the remaining three samples (designated by *b*) each was a duplicate of one of the nitroglycerin-nitropolyglycerin samples, except that it con-

tained ethylene glycol dinitrate in place of nitropolyglycerin. Table I gives data of chemical analysis, density, and rate of detonation.

TABLE II.

Rate of Detonation of Column of Two Cartridges of Explosive 3a Separated by an Air-gap.

Air-gap, inches.	0	1½	3	6	9	12
Rate of detonation of explosive plus air-gap, metres per second.....	1715	1765	1850	2050	1950	1780
	1740	1900	1840	1960	1910	2 shots
	1740	1860	1960	2110	2000	failed
	1760	1800	1910	2120	1970	to deto-
						nate
	1650	1830	1820	1885	2010	
	1690		1970	2030	1980	
	1870		1965	2110	2070	
	1665			2100	2070	
Average.....	1730	1830	1900	2050	2000	1780
Average deviation (a.d.).....	49	39	57	64	43	
Per cent. average deviation.....	2.8	2.1	3.0	3.1	2.2	
Average deviation of the mean (a.d.) per cent.....	1.0	0.9	1.1	1.1	0.8	
Calculated average velocity over air-gap, metres per second.....	1730	3050	2700	2510	2230	1800

Table II gives the results of individual determinations made with explosive *3a* for air-gaps of 0, 1½, 3, 6, 9, and 12 inches, arranged as shown in Fig. 1.

TABLE III.

Rate of Detonation of Two Cartridges of Explosive Separated by Air-gap.

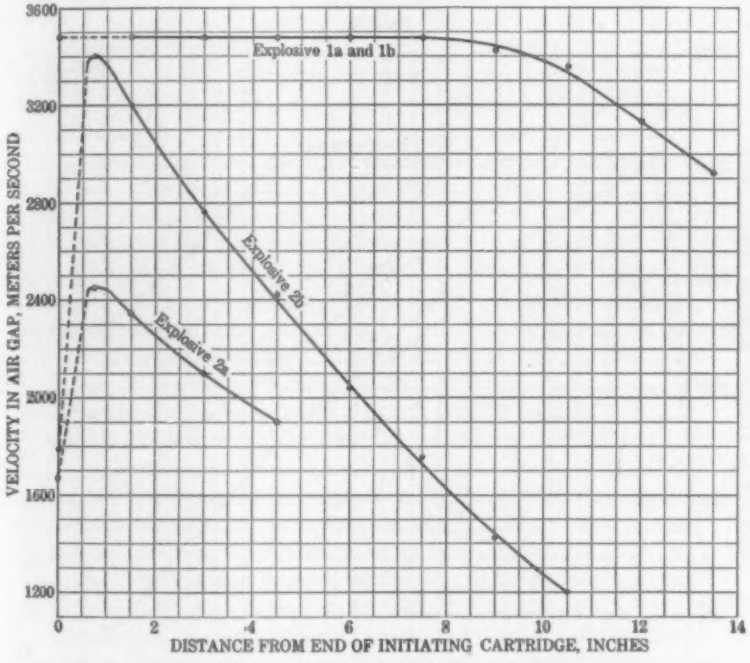
Length of Air-gap, inches.	0	1½	3	6	9	12	15	18	24	30	36	42	48
Average rate of explosive plus air-gap—													
Explosive 1*a*	3480	....	3470	3470	3390*								
1*b*	3480	....	3400	3490	3500	3440	3370						
2*a*	1670	1740	1800	1860									
2*b*	1790	1900	2020	2080	2065	2040							
3*a*	1730	1830	1900	2050	2000	1780							
3*b*	1750	1905	1955	2110	2135	2015							
4*a*	2820	....	2750	2810	2840	2700							
40 per cent. dynamite...	4840	....	4830	4780	....	4440	....	4020	3590	2820	2360	2190	1530

*Average of two determinations only. Probably that actual average rate is about 3480.

The second cartridge did not detonate when the air-gap was increased beyond 12 inches. The average rates given under the

columns representing the various air-gaps are the rates of propagation between the two copper wires threaded through the two cartridges of explosive and hence are the resultant of the rate of propagation through the length of explosive included between the wires plus the rate of propagation of the shock wave across

FIG. 2.



Velocity of propagation of disturbance in air-gap between two cartridges of explosives.

the air-gap. Calculation of the rate of propagation across the air-gap is carried out as follows:

For example, in Table II the rate of the explosive alone is 1730 metres per second, while when a 3-inch air-gap is employed as shown in Fig. 1*c*, the rate was 1900 metres per second. This latter value was obtained over a distance of 12 inches, which included 3 inches of air-gap and 9 inches of explosive. As there are three lengths of explosive to one of air-gap, and if we call x the rate of propagation across the air-gap in metres per second, we may write the following equation between the time intervals

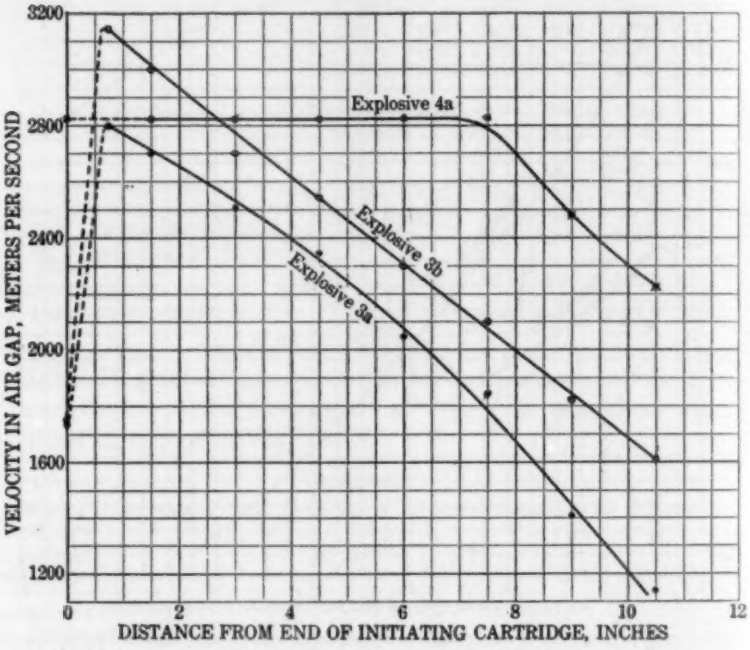
required for the impulse to travel across the explosive, the air-gap, and explosive and air-gap, respectively.

$$\frac{3}{1730} + \frac{1}{x} = \frac{4}{1900}$$

x = 2700 metres per second.

This value, 2700 metres per second, is the average velocity of propagation of the shock wave over a 3-inch air-gap. Similar

FIG. 3.



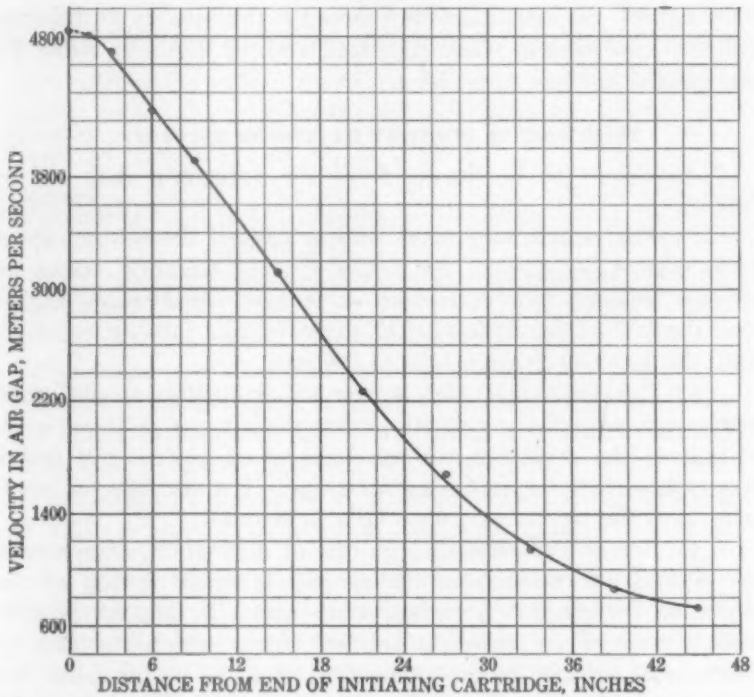
Velocity of propagation of disturbance in air-gap between two cartridges of explosives.

values have been calculated for the 6-, 9-, and 12-inch gaps. The rate of propagation of the shock wave across the air-gap is thus shown to be considerably greater than the rate of detonation of the explosive over the first 9 inches of air-gap and even at 12 inches, where the second cartridge detonated only in one shot out of three, the average velocity of the shock wave is about equal to that of the explosive.

Average values are given in Table II. For example, the velocity over the 9-inch gap, 2230 metres per second, is the resultant of higher velocities over the first part of the gap and

lower velocities over the latter part of the gap. If the decrease in velocity across the gap were linear, then the value 2230 would represent the actual or instantaneous velocity at a point in the air-gap 4½ inches from the end of the first cartridge. To indicate better the values of the velocity at different points in the gap, a series of " instantaneous " values have been calculated over 3-inch intervals. For this purpose a smooth curve is drawn

FIG. 4.



Velocity of propagation of disturbance across an air-gap between two cartridges of 40 per cent. nitroglycerin dynamite.

through the average values as given in Table II, and calculations made as follows:

For example, the average velocity over a 9-inch air-gap is 2230 metres per second and over a 12-inch air-gap is 1800 metres per second. The average velocity over the interval 9–12 inches or the instantaneous velocity at a point 10½ inches from the end of the first cartridge is calculated as follows:

$$\frac{3}{2230} + \frac{1}{x} = \frac{4}{1800},$$

whence x, the velocity over the 9–12-inch region, equals 1140 metres per second.

Averages of the original data are given in Table III. At least three determinations were made to obtain these averages, and in many cases as high as eight separate determinations were made. The average deviation of the mean (a.d.) was in all cases 1.25 per cent. or less. The calculated values for average velocity across the air-gap were then plotted as smooth curves and from these curves, the instantaneous values for the velocity at different points in the air-gap were calculated and set down in Table IV and plotted in Figs. 2, 3, and 4.

DISCUSSION OF STUDY BY METTEGANG RECORDER.

Conclusions to be drawn from the foregoing data are as follows:

(1) For certain explosives of low rate of detonation, about 1700 metres per second, the velocity of propagation across an air-gap between two cartridges is at first considerably higher than the rate of detonation of the explosive and falls off regularly until the second cartridge fails to detonate.

(2) For explosives with a rate of detonation around 3000 metres per second the velocity across the air-gap is about equal to that of the explosive over an interval of 4½ to 7½ inches from the end of the initiating cartridge. It then falls off regularly until the second cartridge fails to detonate.

(3) For an explosive of high rate of detonation, 4800 metres per second, the velocity in the air-gap is equal to that of the explosive for about 1½ inches, after which it falls off linearly until a gap of 27 inches is reached, after which the rate of decrease of velocity is less rapid until at a gap of 48 inches the second cartridge does not always detonate. The velocity over the interval 42–48 inches is about 730 metres per second.

(4) Explosives that contain ethylene glycol dinitrate as a low-freeze ingredient propagate across a greater air-gap than do similar explosives containing nitropolyglycerin and maintain a higher average velocity across the air-gap. This is particularly evident in the case of the explosives of low rate of detonation.

These results are borne out by an interesting series of experiments in which a charge was made up which consisted of 4-inch lengths of explosive separated by 3-inch air-gaps. If the results

plotted in Figs. 3 and 4 be considered, such a charge should detonate at a higher rate than a solid column of explosive if a low-rate explosive is used. Three determinations each were made on charges of explosive *2a*, (1) with no air-gaps and (2) with four 3-inch air-gaps (Fig. 1, *G* and *H*). In the latter case, the length over which the rate was measured included 17.5 inches of explosive and 12 inches of air-gaps. The rate for the solid explosive column was 1650 metres per second, while the rate of

TABLE IV.

Calculated "Instantaneous" Values of Velocity of Propagation of Disturbance across Air-gap.

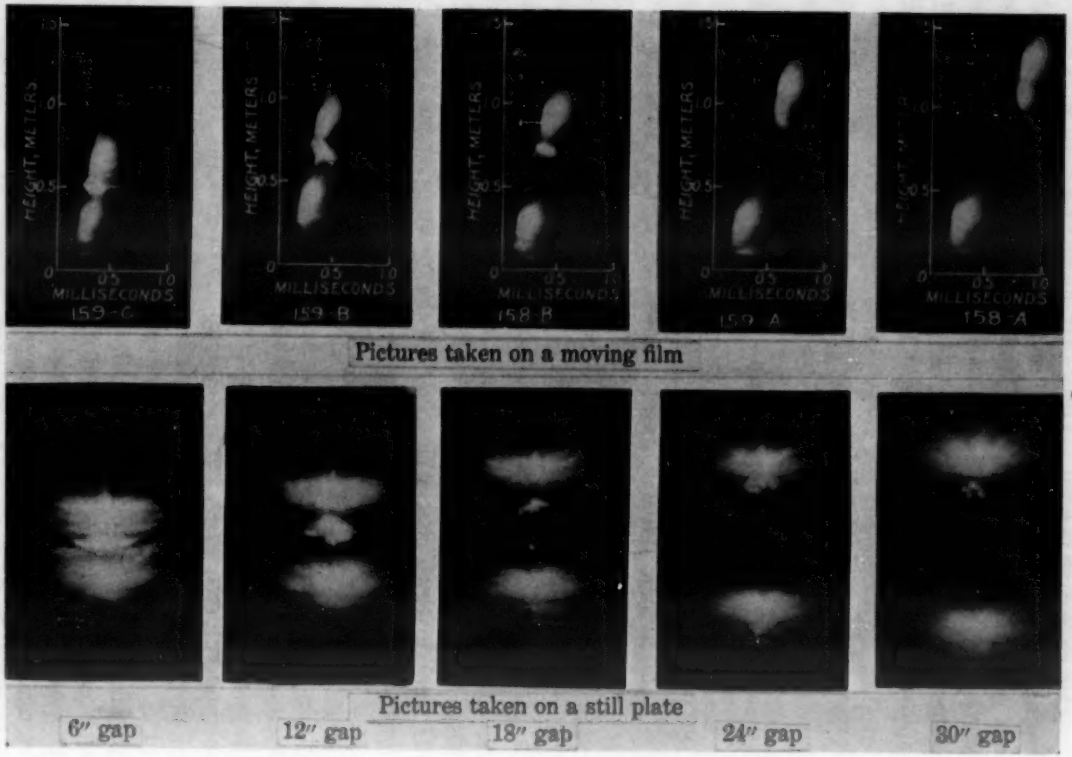
Interval, inches	0	0–1.5	0–3	0–6	3–6	3–9	6–9	6–12	9–12	9–15	12–15
Mid-point	0	0.75	1.5	3	4.5	6	7.5	9	10.5	12	13.5
Velocity of propagation, metres per second—											
Explosive *1a*	3480	....	3480	3480	3480	3480	3480				
1b	3480	....	3480	3480	3480	3480	3480	3420	3360	3130	2920
2a	1670	2450	2350	2100	1900						
2b	1790	3400	3200	2760	2420	2040	1760	1420	1200		
3a	1730	3050	2700	2510	2350	2050	1840	1410	1140		
3b	1750	3140	3000	2760	2540	2300	2100	1820	1610		
4a	2820	....	2820	2820	2820	2820	2820	2480	2220		

the column containing the air-gaps was 1880 metres per second. The rate of propagation across the air-gaps is thus 2350 metres per second, which checks closely with the figure given in Table IV for the value of the velocity of propagation across a 3-inch gap.

MEASUREMENT BY PHOTOGRAPHIC METHOD.

In order to check the conclusions from tests with the Mettegang recorder and to record the physical appearance of the phenomenon, experiments were carried out by the photographic method referred to in the introduction. In general, the method of preparing the charge was as follows: Two or three cartridges (1¼ by 8 inches) with the ends cut off were wrapped in two thicknesses of Manila paper with the desired air-gap between adjacent cartridges. A No. 6 electric detonator was placed in the bottom end of the lower cartridge. The whole was suspended vertically in the air and a photograph of the detonation taken both on a fixed plate and on a film moving at 20 metres per second. Fig. 5 shows photographs of the detonation of two cartridges of 40 per cent. ammonia dynamite with 6- to 30-inch air-gaps between the cartridges. The figure shows that the shock

FIG. 5.



Photographs of detonation of charges of 40 per cent. ammonia dynamite separated by an air-gap.

wave travels for the first 6 inches at about the same rate as the explosive, falls off fairly regularly until a gap of 24 inches is reached, and then somewhat more slowly over the next 6 inches. The second cartridge failed to explode at distances greater than 30 inches.

Attention is called to the bright spot near the lower end of the upper cartridge which sometimes shows up as an umbrella-shaped surface in the pictures on the fixed plate, which is probably due to the meeting of the expanding gases from the upper cartridge with the remainder of the upward moving gases from

TABLE V.

Rate of Propagation of Disturbance across an Air-gap between Two Cartridges by Photographic Method.

(*A*) Average velocity from top of lower cartridge to bottom of upper cartridge.

Air-gap, inches.	0	6	12	18	24	30	36	48
Velocity, metres/sec.								
(*a*) 40 per cent. ammonia dynamite	3600	3500	3400	2800	1800	1400		
(*b*) 40 per cent. nitroglycerin dynamite	4600	4600	3800	....	3000	....	2000	1200

(*B*) Velocity over 6-inch intervals calculated from data in *A*.

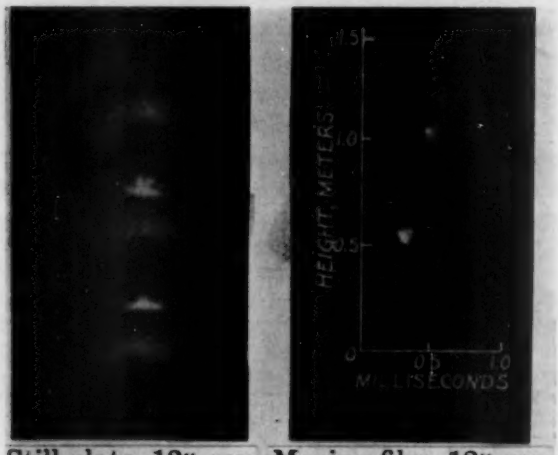
Interval, inches.	0	0–6	6–12	12–18	12–24	18–24	24–30	24–36	36–48
Velocity, metres/sec.									
(*a*) 40 per cent. ammonia	3600	3500	3300	2100	....	870	740	...	...
(*b*) 40 per cent. nitroglycerin	4600	4600	3300	....	2500	...	...	1200	550

the lower cartridge. Measurement of the photograph shows that this bright spot is not in the position occupied by the bottom of the upper cartridge, but is below the upper cartridge.

A similar series of experiments was carried out with 40 per cent. straight nitroglycerin dynamite.

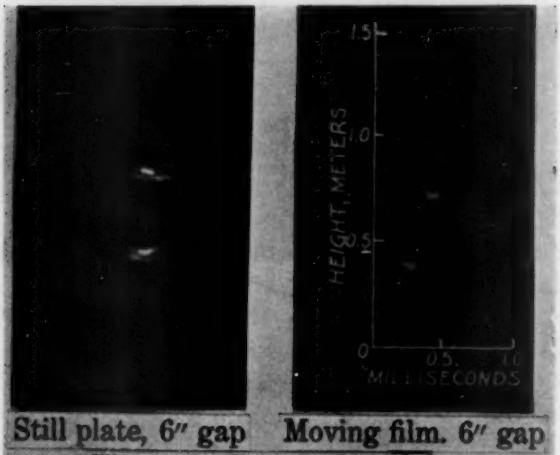
The calculated values for the rate of propagation of the disturbance between cartridges are shown in Table V, *A* and *B*. The values for 40 per cent. nitroglycerin dynamite agree fairly well with those obtained with the Mettegang recorder. The sample of dynamite used detonated at a somewhat lower rate than that used for the work with the Mettegang recorder.

Fig. 6 shows three cartridges of permissible *B* in a paper tube separated by a 12-inch air-gap between adjacent cartridges.



Still plate, 12″ gap Moving film, 12″ gap

Figure 6.- Permissible 'B'



Still plate, 6″ gap Moving film. 6″ gap

Figure 7.- Permissible 'D'

The average rate of detonation of the explosive, including the air-gaps, was found to be 2750 metres per second from measurements made on the negative, as compared with 2980 metres per

second for the explosive itself. Fig. 7 is a similar photograph of permissible *D* separated by a 6-inch air-gap. Six inches was found to be the limit of propagation of detonation through an air-gap for this explosive. The average rate of detonation of the explosive and air-gap was 2400 metres per second from measurements made on the negative as compared with 2040 metres per second for the explosive itself. Both Fig. 6 and Fig. 7 show bright or umbrella-shaped light spots between the cartridges of

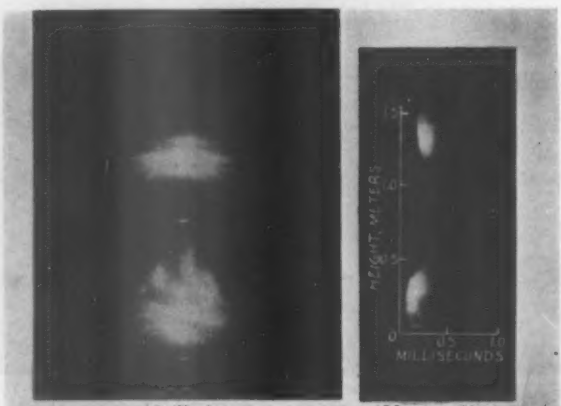


Figure 8.- Detonation from opposite ends simultaneously. 40 per cent nitroglycerine dynamite, 36" air gap.

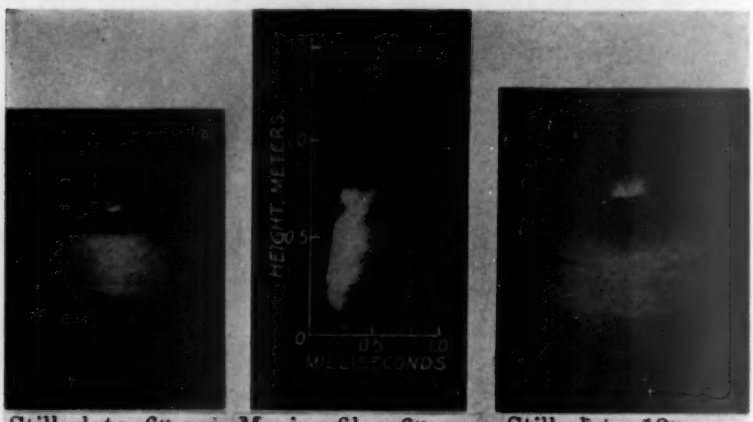
explosive. Fig. 7 especially shows up well; the bright spot is more luminous than the light given off by the explosive. The results of these two experiments agree well with tests made on the Mettegang recorder with explosives of nearly the same rate.

Fig. 8 shows a photograph obtained by detonation from opposite ends simultaneously of a column consisting of two 1¼ by 8-inch cartridges of 40 per cent. nitroglycerin dynamite separated by a 36-inch air-gap. The bright spot near the upper cartridge indicates the point where the gases met.

Fig. 9 shows 6- and 12-inch air-gaps between two cartridges in a paper tube in which the upper cartridge was a dummy made of kieselguhr in a paper wrapper. As there was no explosive in the upper cartridge it was desired to observe whether a bright or umbrella-shaped spot of light would occur between the two cartridges. Such was not the case; the bottom of the upper

cartridge shows a luminescence effect but the light spot is not of the same shape or in the same position. It shows the same straight line always obtained when the gaseous products are projected against any solid object.

Fig. 9 also shows that increased luminosity results when the gases are projected against a solid object, while Fig. 8 shows increased luminosity when detonation waves meet. At this meet-



Still plate, 6″ gap Moving film. 6″ gap Still plate, 12″ gap

Figure 9.- 40 per cent nitroglycerine dynamite, upper cartridge a dummy.

ing point an increased concentration of combustible gases would result and an increased pressure and thus we should expect a more intense light effect.

EFFECT OF CONFINEMENT.

In the work previously described, the explosive was wrapped in two thicknesses of Manila paper, which would offer only slight confinement to the explosive and gases. The next question which naturally arises is, what will be the effect of confinement on the phenomenon of propagation across an air-gap? Preliminary tests by the photographic method in which the explosive was confined in a glass tube were made as follows:

For the photograph in Fig. 10 a glass tube 1 inch in diameter and 47 inches long was loaded at one end with 40 per cent. standard dynamite for a distance of 12½ inches. The tube was

suspended from a vertical wire with the explosive at the bottom end of the tube. The luminous effect in the glass tube extends 35 inches from the end of the explosive charge. Its velocity is very high at the start, with a gradual decrease over the length of the luminous part of the tube. The velocity of the first 2 inches of the luminous effect is approximately 6000 metres per second compared with 4170 metres per second for the velocity of the

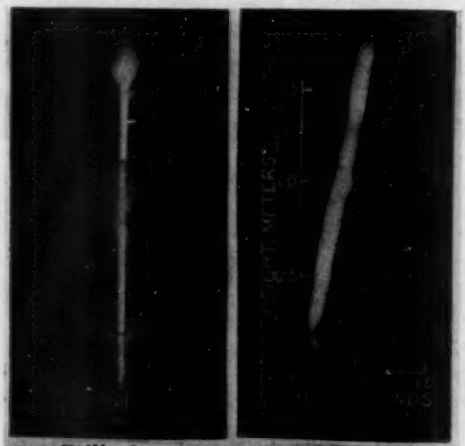
Figure 10.- 40 per cent nitroglycerine dynamite.

Explosives confined in glass tubes.

explosive. The velocity of the last 4 inches of the luminous part of the tube is approximately 2500 metres per second.

Fig. 11 is a similar glass tube with two charges of 40 per cent. standard dynamite and an air-gap between them. A 12-inch charge of 40 per cent. standard dynamite was loaded in one end of the tube followed by another 12-inch charge 21½ inches from the first charge. This photograph also shows the increased velocity of the luminous effect in the glass tube over the rate of detonation of the explosive for a short distance along the length of the tube. The average rate of detonation between the centres of the explosive charges was found to be 3700 metres per second; the average rate of detonation of the explosive from measurements made on the negative was 3800 metres per second. The latter determination was made measuring the rates of the two charges 12 inches long and averaging the results. The average velocity

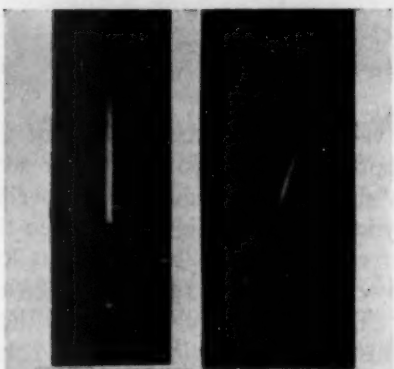
of propagation over the 21½-inch air-gap is almost the same as the rate of detonation of the explosive.



Still plate Moving film

Figure 11.- 40 per cent nitroglycerine dynamite.

Explosives confined in glass tubes.



Still plate Moving film

Figure 12.- Permissible 'D'

Explosives confined in glass tubes.

In both Figs. 10 and 11, it should be noted that the point of initiation, that is, the location of the detonator, was not at the zero mark on the metric scale on the photograph. The bottom

of the tube was not closed and the flame from the explosive projected downward is evident in the photographs.

Fig. 12 is a charge of 14½ inches of permissible *D* in a glass tube, 1 inch in diameter. The length of the luminous effect in the tube is much shorter and the relation between its rate of propagation and the rate of detonation of the explosive is proportion-

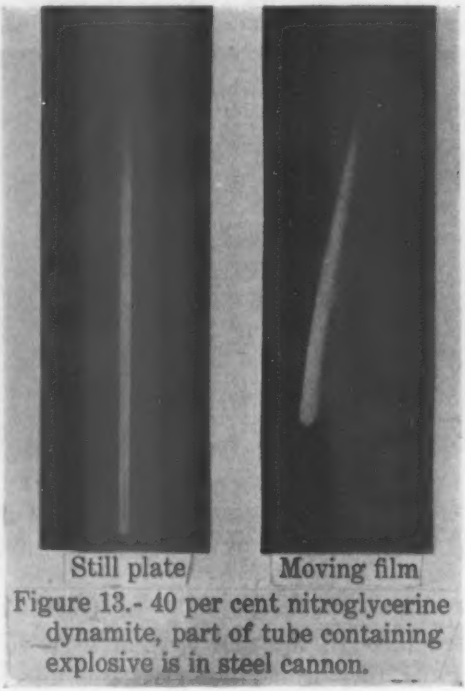


Figure 13.- 40 per cent nitroglycerine dynamite, part of tube containing explosive is in steel cannon.

Explosives confined in glass tubes.

ately higher than was found with 40 per cent. standard dynamite. The rate of propagation of the luminous effect is approximately 4500 metres per second for the first 2 inches of its length compared with a rate of propagation of 2000 metres per second for the explosive. The presence of lead tetraethyl or carbon tetrachloride in the tube destroys the luminous effect.

Fig. 13 is a charge of 40 grams of 40 per cent. standard dynamite shot in a cannon with a glass tube extending out of the borehole of the cannon. The cannon had a borehole 7 inches deep and 1¼ inches in diameter with a glass tube 1 inch inside diame-

ter and 5 feet long placed in the borehole. The luminous effect in the tube is similar to that of Fig. 10, with the exception that the gaseous products of the detonation of the explosive must emerge through the tube before it is broken or in the space formerly occupied by the tube if it breaks first. The luminous darts all along the sides of the tube indicate the reaction of gases after the tube has broken. This shows that the reacting gases

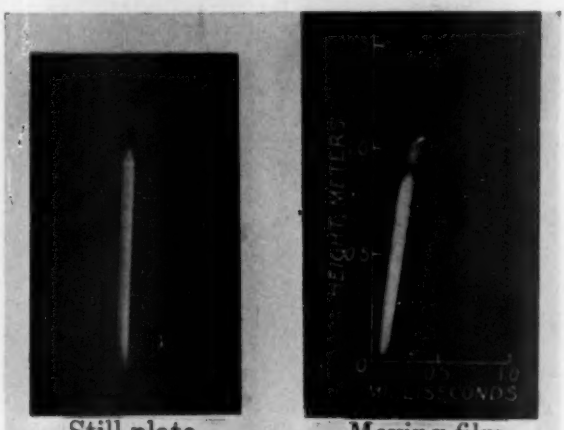


Figure 14.- Permissible 'D', part of tube containing explosive is in steel cannon.

were propagated through the tube first at high velocity before it broke, otherwise they would not give luminous effects at so great a distance from the borehole.

In Fig. 14, a short glass tube that extended 21 inches beyond the mouth of the borehole was used in place of one 5 feet long. Permissible *D* with a low rate of detonation was used in place of 40 per cent. standard dynamite. Here the velocity of the luminous effect in the tube is 5400 metres per second, compared with 2010 metres per second, the velocity of the explosive. There is a flame coming from the top of the tube with no time interval between it and the luminous effect at the top of the tube, which would seem to show the presence of reacting gases in the tube propagated at the velocity of the luminous effect.

DISCUSSION OF PHOTOGRAPHIC STUDY.

Photographs on a moving film in general confirm the results obtained with the Mettegang recorder, which are, for explosives detonating at a rate of 2000 metres per second or less, the propagation of the disturbance across an air-gap is at first faster than the rate of detonation of the explosive.

When the explosives are confined in glass tubes, the speed of the disturbance is considerably greater than the rate of detonation of the explosive and is maintained for a longer distance. In this case, a luminous phenomenon is propagated through the air-gap in the tube and seems to be coincident in time with the disturbance responsible for detonating the second cartridge.

Laffitte [8] believes that the pressure wave or shock wave sent out by the explosive raises the temperature of the air by compression to such an extent that it becomes luminous. The writers do not favor this explanation, but do not at present have conclusive proof of any other mechanism. It is their belief, however, that for the extremely brief time-intervals involved, the glass tube offers such confinement that the gases from the explosive are projected up the tube and that the luminous phenomenon in the space above the explosive is due to the reacting gases. The following experimental facts are of interest in this connection: (1) If the glass tube is placed in a steel cannon so that the gaseous products of detonation are projected through the tube, a luminous phenomenon is propagated from the end of the tube with no time interval between it and the luminous phenomenon in the tube. (2) Luminous darts along the sides of the tube indicate that reacting gases were projected up through the tube before it broke. (3) Flames of explosives fired in a steel cannon are projected from the cannon at a higher rate than the rate of detonation of the explosive when the explosive is near the mouth of the borehole and at a lower rate when the explosive is further from the mouth.[9]

Further experimental work in connection with this phenomenon is in progress and measurements with the Mettegang recorder

[8] See reference 5.

[9] See reference 6.

are being extended to the case of propagation across an air-gap between cartridges of explosive confined in Shelby steel tubes.

This investigation was undertaken at the suggestion of Dr. Charles E. Munroe, Chairman, Committee on Explosives Investigations, National Research Council.

A Low Voltage Arc in Vacuum. K. L. WOLF. (*Zeit. f. Phys.*, **39**, No. 12, 1926.)—In experiments on the electrical excitation of iron vapor a tube of Acheson or Siemens graphite with an external diameter of 20 mm. and an internal diameter of 12 mm. was kept at a temperature of about 2000° C. by the passage of a current of 1000 amperes under a potential difference of 10 volts. With the passing of time this tube grew thinner in the middle and finally burned completely through, and an arc formed between the resulting ends. If the voltage was raised to 15, at the moment of the appearance of the arc, it could be maintained for a long time. By regulating the field excitation of the dynamo providing the current both the voltage and the current were so raised as to keep the arc burning as the tube continued to waste away. Thus the tube finally disappeared completely and the arc burned between the carbon blocks that had supported the tube. Then its length was 15 cm. with 18 volts and 900 amperes. For the preservation of other parts of the apparatus it was necessary to stop the intense illumination after 30 or 60 minutes. In this experiment the arc was in a space kept at a pressure ranging from .01 to .1 mm. of mercury.

Advantage was taken of the above-mentioned intense arc to study the line 4267 Å.U. of the carbon spark spectrum. Photographed by a Rowland plane grating the two components appear distinctly separated. The difference in their wave-lengths is .231 Å.U., and one of them is more than twice as intense as the other. G. F. S.

Crude Oil Production.—The American Petroleum Institute estimates that the daily average gross crude oil production in the United States for the week ended February 19th was 2,472,000 barrels as compared with 2,462,250 barrels for the preceding week, an increase of 9750 barrels. The daily average production east of California was 1,832,000 barrels, as compared with 1,820,750 barrels, an increase of 11,250 barrels.

The estimated daily average gross production of the Mid-Continent field including Oklahoma, Kansas, Panhandle, North, West Central, East Central and Southwest Texas, North Louisiana and Arkansas, for the week ended February 19th was 1,488,150 barrels, as compared with 1,468,250 barrels for the preceding week, an increase of 19,900 barrels. The Mid-Continent production, excluding Smackover, Arkansas heavy oil, was 1,386,050 barrels as compared with 1,365,700 barrels, an increase of 20,350 barrels.

A NOTE ON THE MEASUREMENT OF SMALL TIME INTERVALS.

BY

PHILIP P. QUAYLE.

Assistant Physicist, Sound Section, Bureau of Standards.

On account of many discrepancies in the literature on the subject, the Sound Section of the Bureau of Standards has undertaken an investigation of the effects of temperature and amplitude on the frequency of tuning-forks of various materials. For this purpose it is necessary to have a standard of time of high accuracy.

We frequently read accounts of short time measurements with tuning-forks, clocks, etc., in which very high accuracies are claimed. However, it must be kept strictly in mind that measurements of this type represent the average over the period and convey no information whatever as to the variations from second to second. While the best chronometers may keep time very accurately over relatively long periods, the variation from second to second of the signals they furnish, may be of the order of 0.002 second, an error unfitting them for work of the highest precision over short intervals.

The standard of time with which the above-mentioned investigations at the Bureau of Standards were begun consisted of a very expensive break circuit chronometer of one of the most approved makes. Using this instrument, a point was soon reached at which the uncertainties in the time interval completely masked the phenomenon under investigation.

The free pendulum is doubtless the most accurate timekeeper known at present, but due to its relatively slow motion the difficulties of applying it to very short time measurements has heretofore been great. It is true that if the frequency of a fork is already accurately known, certain types of apparatus have been devised whereby the precision may be somewhat extended. However, in general, in rating a tuning-fork against a pendulum sending flashes directly into a high-speed camera, not only are we unable to determine in what fraction of a fork cycle the second

terminates, but we often cannot identify the nearest ten cycles in which the period comes to an end. With the apparatus described in this paper this difficulty is removed and we have available a time standard applicable to a very great many types of investigation.

Generally speaking the apparatus described in this paper is not unfamiliar but the application is believed to be somewhat unusual and likely to be of interest in the precise measurement of short time intervals.

The use of a photo-electric cell actuated by flashes from a pendulum for the distribution of time signals is of course by no means new. Arrangements of this kind have been employed by some of the industries for a number of years and for the degree of accuracy required have apparently given satisfaction. However, all of these systems of which we are aware have utilized the current from the cell to operate a relay of some kind. Even the best of relays fitted with jewelled bearings and operating under ideal laboratory conditions show an extreme variation of a few ten-thousandths of a second. The ordinary relay without these refinements may easily vary several thousandths of a second. Hence it will be evident that the great accuracy of a free pendulum is by no means conserved by a relay of the type just mentioned.

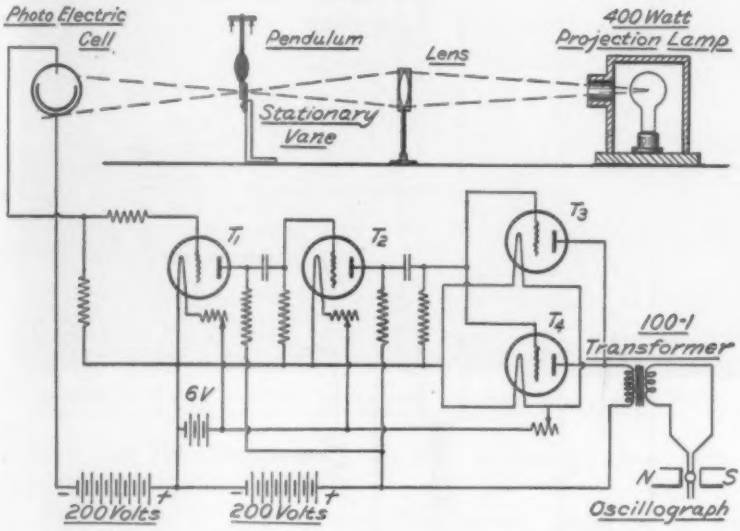
The free pendulum employed in this work was obtained from the Coast and Geodetic Survey and swings *in vacuo*. The pendulum bob has a steel knife edge let into its lower side, the blade of which registers with a similar stationary knife edge adjustable from the outside of the pendulum case.

By means of a 400-watt projection lamp and suitable lens an image of one of the lamp filaments is formed on the knife edges. When the pendulum is swinging the light passes through the pendulum case for one-quarter second and is then cut off for a like period.

The beam of light which passes through the pendulum case falls on a potassium hydride photo-electric cell suitably connected to a three-stage resistance coupled amplifier. A step-down transformer of approximately 100 to 1 ratio is placed in the output circuit of this amplifier and the output leads are connected to a standard General Electric oscillograph element. The light beam

from this element is received on a special high-speed camera [1] which takes a four-inch film five feet in length. By means of the spiralling drum with which this camera is equipped a record forty feet in length is readily obtained. The oscillograph element just mentioned vibrates about a vertical axis and at each swing of the pendulum the beam whips across the camera shutter, making an almost horizontal line on the rapidly moving vertical film. Due to the electrical constants of the circuit the beam does not

FIG. 1.



return across the shutter as rapidly as it starts, and hence it is the start to which all measurements are referred.

The manner in which portions of the apparatus have been assembled is shown diagrammatically in Fig. 1. The photo-electric cell is of the potassium hydride gas-filled type and was furnished through the courtesy of the Lynn Works of the General Electric Company. This cell is suitably mounted in a metallic case and when the light is off its resistance is practically infinite. The so-called dark currents are negligibly small.

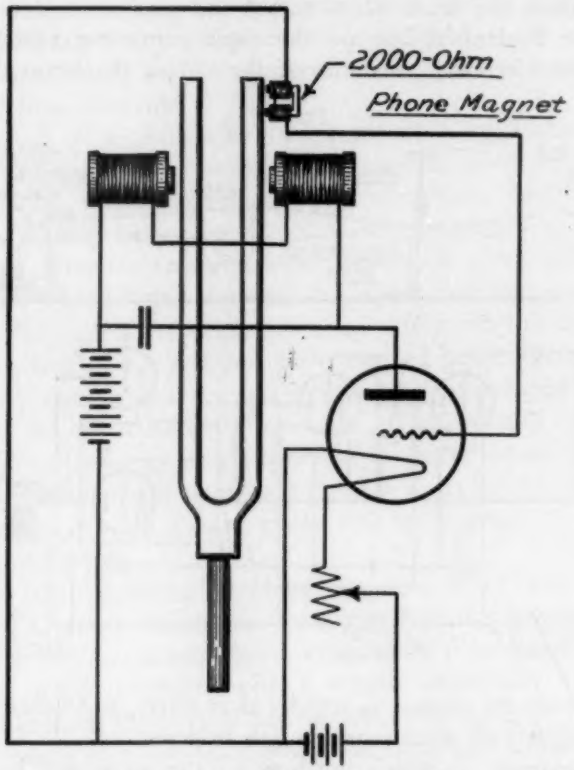
Under the stimulus of the light, the cell becomes conducting with a resulting fall of potential on the grid of the first tube.

[1] E. A. ECKHARDT, "A Precision High-speed Oscillograph Camera," JOUR. FRANK. INST., July, 1922.

The pulse thus started is amplified and, by means of the special step-down transformer in the output circuit of the last stage, operates the oscillograph element as already described.

The tubes in stages T_1 and T_2 are type 102-D Western Electric Company, and those in the last stage are type 205-D Western Electric Company, and are connected in parallel.

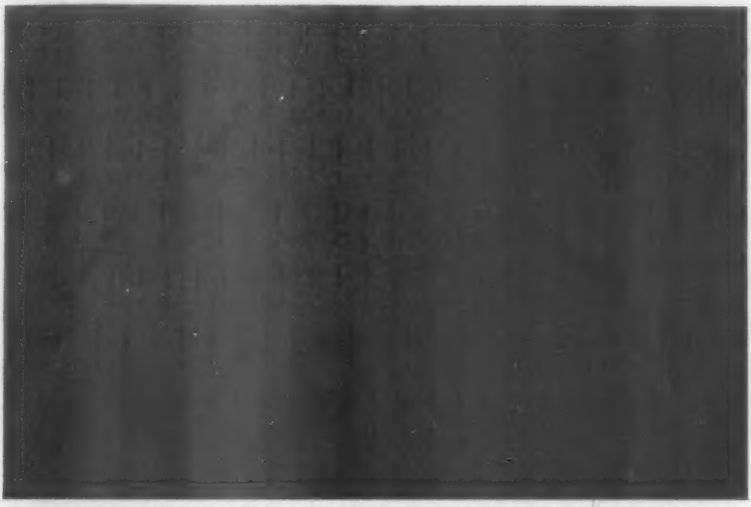
FIG. 2.



In the initial test of the pendulum system two entirely independent tuning-forks were rated against the pendulum simultaneously. If only one fork is rated against the pendulum and we find that successive seconds do not contain an equal number of vibrations, we should not know whether the fork or the pendulum apparatus were at fault. If, however, two forks are rated against the pendulum simultaneously, and we find that when a given interval contains too small a number of vibrations with

one fork it also contains too small a number of vibrations of the other, then we may assume that the fault lies in the pendulum apparatus. If the residuals of the two forks for corresponding seconds show a chance distribution of sign, we may reasonably

FIG. 3.



Photographic record of the oscillations of the tuning-forks against the pendulum. The portions of the pendulum transits to which all measurements are made are marked with a "T".

assume that the discrepancies are due, at least in large part, to the forks themselves.

Proceeding in this manner the records given below have been obtained.

It may be well to state at this point that the actual motions of the forks themselves were not recorded, but in reality their driving currents. Each fork was driven by a suitable vacuum tube drive such as is indicated in Fig. 2, and proved to be remarkably steady. The operation and theory of this type of circuit has been discussed by Butterworth.[2] The plate and filament supply for the 259-cycle fork was taken from the 220-volt power mains while the 217-cycle fork was provided with separate *A* and *B* batteries. In the plate circuit of each fork drive a step-down transformer was inserted, the output of which was used to drive a separate oscillograph element registering the variations in

[2] *London Phys. Soc.*, 32, 1919–1920.

plate current for that particular fork drive. The type of drive indicated in Fig. 2 has the advantage that it is entirely dependent upon the actual motion of the fork, while some other forms will continue to oscillate after the fork has been removed from its mounting.

In Fig. 3 is shown a portion of a film record obtained by this method. The actual values as determined by a small comparator are given below.

Film 19. September 20, 1926.

Temperature, 24° C.

259	Fork.	217	Fork.
259.10	.00	217.49	.00
.11	−.01	.50	−.01
.10	.00	.51	−.02
.09	+.01	.48	+.01
.08	+.02	.49	.00
Mean 259.10		Mean 217.49	

Contrary to what we would naturally expect, the 259-cycle fork operating on the power mains apparently maintains its frequency with fully as much precision as the 217-cycle fork driving on separate *A* and *B* batteries.

The amplifier used in these experiments was carefully shielded and the shield grounded. Nevertheless, the greatest care must be exercised to avoid stray fields if the maximum precision is to be obtained. For instance, it was found that even when the camera driving motor was cut off and the solenoid shutter operated by hand, a sufficient electromagnetic field was set up so that the first second in every trial was always long by as much as four parts in 25,000. As soon as such disturbing influences were eliminated the abnormal first second disappeared.

The probable error of the mean of the five observations given above is less than one part in 40,000 for each fork.

It will be evident that very accurate time signals could be distributed from such a system if desirable.

The writer is indebted to Mr. Harold Wheeler and Mr. Vernon Whitman for their kind interest and suggestions in the initial experiments.

THE SIGNIFICANCE OF THE DIELECTRIC CONSTANT OF A MIXTURE.*

BY

HOMER H. LOWRY, Ph.D.

Bell Telephone Laboratories, Incorporated.

IN MANY cases it would be of great value to be able to calculate either the dielectric constant of a mixture of substances of known dielectric constants or, knowing the dielectric constants of a mixture of two components and that of one of the components, to calculate the dielectric constant of the other. A review of the literature, however, shows that this can be rarely accomplished. This is due mainly to the inadequacy of the theories of dielectrics, all of which are insufficiently developed to include the dielectric behavior of mixtures. Nevertheless, as will be shown, many attempts have been made to develop formulæ of theoretical significance for application to mixtures. Inspection of the derivation of these formulæ shows that those with the best theoretical background are limited to such special cases that they are of practically no value.

Following a brief review of these formulæ there will be given a brief account of the results of experimental investigations on the dielectric behavior of mixtures. For convenience in presentation the experimental data will be subdivided into the following sections: (*a*) Liquid-liquid mixtures; (*b*) electrolytic solutions; (*c*) non-electrolytic solutions; (*d*) colloidal solutions; and (*e*) mixtures showing a high degree of heterogeneity, such as powders in air.

A bibliography is appended and the references throughout the paper will refer to this list.

A. THEORY.

Three main formulæ have been proposed to represent the relation between the dielectric constant of a pure substance and its density d:

* Communicated by the Author.

$$\frac{\sqrt{\varepsilon}-1}{d} = \text{constant} \qquad \text{(Beer, Landolt, Gladstone)}^{37} \qquad (1)$$

$$\frac{\varepsilon-1}{d} = \text{constant} \qquad \text{(Newton, Laplace)}^{37} \qquad (2)$$

$$\frac{\varepsilon-1}{\varepsilon+2}\cdot\frac{1}{d} = \text{constant} \qquad \text{(Clausius,}^{8}\text{ Mossotti,}^{37}\text{ Lorenz,}^{41}\text{ Lorentz,}^{40}\text{ Rayleigh,}^{31}\text{ Debye}^{11}\text{)} \qquad (3)$$

Of these formulæ, (3) undoubtedly has the most theoretical significance, having been derived independently by the six investigators given in the parentheses. In spite of this fact, where investigations have been made over a sufficiently wide temperature range to allow a thorough test of the applicability of the formula,[26, 42, 58] deviations well without the experimental error have been noted even for pure liquids. Introduction of an additional term to take care of the influence of temperature on the dipolar moment † of the molecules, as has been done by Debye [10] and Isnardi and Gans,[30, 31] has not proven sufficient.[26]

The methods of derivation of formula (3) are briefly as follows:

On the assumption of Faraday that dielectrics consist of spherical, not touching, conducting bodies, Mossotti ‡ developed a mathematical theory of dielectric polarization in the same way as Poisson had treated the problem of induced magnetism. Indepently Clausius treated the problem analogously and with the assumptions (1) that the molecules are rigid spheres, (2) that they are good conductors, and (3) that the intervening space is a perfect insulator, he arrived at the relation:

$$\frac{\varepsilon-1}{\varepsilon+2} = g, \qquad (4)$$

where g is the ratio of the space x, occupied by the molecules to the total volume V. Since at constant mass V is inversely proportional to the density d, it follows that

† A dipole is a molecule in which the electrical centre of gravity of the positive charges $+E$ is not coincident with the electrical centre of gravity of the negative charges $-E$, but is separated by a distance L. The product $M = E \cdot L$ is then designated the dipolar moment of the molecule.

‡ References to the original papers of Mossotti have been hard to find. They are given by Beaulard [2] and are given in the following, although the originals have not been consulted: F. O. Mossotti, *Arch. des Sc. phys. et nat. de Genève*, VI, 193, 1847, and *Mem. di Mat. et di Fis. della Soc. ital. Modena*, **14**, 49, 1850.

$$\frac{\varepsilon - 1}{\varepsilon + 2} \cdot \frac{1}{d} = \frac{x}{V} \cdot \frac{1}{d} = kx, \tag{5}$$

where k is a proportionality factor. If x is assumed to be constant, the so-called Clausius-Mossotti relation,

$$\frac{\varepsilon - 1}{\varepsilon + 2} \cdot \frac{1}{d} = \text{constant}, \tag{3}$$

follows.§

Lorentz[40] assumed (1) that ether is present between the molecules of a body, (2) that the ether has the same properties as in space except in the immediate neighborhood of the molecules, (3) that in each molecule of an isotropic body an electrical moment will be set up proportional to the e.m.f. and similarly directed, and (4) that Coulomb's Law holds for small distances. Calculation then leads to a relation between the specific inductive capacity, ε, of a non-conductor and its density. If, according to Maxwell (assuming the magnetic permeability is equal to 1), $\varepsilon = n^2$, where n is the index of refraction for infinitely long waves, then

$$\frac{\varepsilon - 1}{\varepsilon + 2} \cdot \frac{1}{d} = \text{constant}, \tag{3}$$

and this constant is determined to be, upon certain considerations and assumptions,

$$\text{constant} = \frac{\frac{4}{3}\pi r^3 (3 + 4\pi\varepsilon_0) - 4\pi\varepsilon_0 \cdot \frac{r^3}{H}}{m \quad (3 + 8\pi\varepsilon_0)\frac{r^3}{H} - 8\pi\varepsilon_0}, \tag{6}$$

where r is the radius of the molecule, m its mass, ε_0 the dielectric constant of the ether, which, according to the electromagnetic theory of light, must be a large number, and H a constant of the

§ The same relation has been found in a somewhat different way by Wiedemann[42] and Poincaré.[54] Also Mascart and Joubert,[45] assuming (1) that the molecules are spherical, (2) that they are *non-conductors*, and (3) that they are made of matter having an extraordinarily high dielectric constant, arrived at the relation

$$\frac{d}{g} = \frac{\varepsilon + 2}{\varepsilon - 1} \cdot d = D = \text{constant},$$

where d is the density at which the material has a dielectric constant ε, so that $\frac{d}{g}$ for one substance is a constant and D is the maximum density of the body or the density of its molecules. This is simply the reciprocal of the relation given in formula (3) and so merely gives a different significance to the constant.

molecule. It is clear from this equation that the second term on the right must be equivalent to g in equation (4). Lorenz,[41] from quite a different mode of reasoning, arrived at the identical result given above.

Rayleigh's [51] derivation of formula (3) is more general than those given above and is worked out in much greater detail. The calculation of the dielectric constant is considered only as a special case of the general problem "On the Influence of Obstacles Arranged in Rectangular Order upon the Properties of a Medium." Briefly, if ε_a denotes the specific inductive capacity of the material composing the spherical obstacles, that of the undisturbed medium being unity, the approximate value of ε is given at once by

$$\varepsilon = \frac{(2+\varepsilon_a)(1-\varepsilon_a) - 2d}{(2+\varepsilon_a)(1-\varepsilon_a) + d}. \qquad (7)\|$$

This may also be written in the form given by Clausius

$$\frac{\varepsilon - 1}{\varepsilon + 2} \cdot \frac{1}{d} = \frac{\varepsilon_a - 1}{\varepsilon_a + 2} = \text{constant}. \qquad (3)\P$$

This formula, however, applies strictly only when d is moderate and when the spheres are arranged in cubic order though, doubtless,[51] an irregular isotropic arrangement would give the same result. The next approximation is

$$\varepsilon = 1 + \frac{3d}{\dfrac{\varepsilon_a + 2}{\varepsilon_a - 1} - d - 1.65 \dfrac{\varepsilon_a - 1}{\varepsilon_a + \frac{4}{3}} d^{\frac{10}{3}}}. \qquad (8)^{**}$$

If one does not assume, as was done in the foregoing, that all the molecules in a system are alike but assumes that they are of different kinds, one obtains a formula for the dielectric constant of a mixture. According to Lorenz-Lorentz, first

$$\frac{\varepsilon_m - 1}{\varepsilon_m + 2} \cdot \frac{1}{d}$$

must have a constant value and then between this value and the analogous constants

|| No. 67, original paper.
¶ No. 79, original paper.
** No. 80, original paper.

$$\frac{\varepsilon_1 - 1}{\varepsilon_1 + 2} \cdot \frac{1}{d_1}, \frac{\varepsilon_2 - 1}{\varepsilon_2 + 2} \cdot \frac{1}{d_2}, \text{ etc.,}$$

there must be the following relation

$$\frac{\varepsilon_m - 1}{\varepsilon_m + 2} = v_1 \frac{\varepsilon_1 - 1}{\varepsilon_1 + 2} + v_2 \frac{\varepsilon_2 - 1}{\varepsilon_2 + 2} + \text{etc.,} \tag{9}$$

where ε_m, ε_1, and ε_2 are the dielectric constants of the mixture, components 1 and 2, respectively, and v_1 and v_2 are the ratios of the volumes of the components to the volume of the mixture.

This formula applies only to the case of spheres isotropically arranged at sufficient separation so that each sphere is in a uniform field. It can be shown further that this formula does not apply if a homogeneous substance of dielectric constant ε_1, in the form of spheres, is embedded in a similar substance of dielectric constant ε_2 *in case* ε_2 *is different from* ε_1. For if we assume that in a second mixture of the same form as the first the dielectric constants of the constituents are n times as great as before, one obtains the following formula

$$\frac{\varepsilon'_m - 1}{\varepsilon'_m + 2} = v_1 \frac{n\varepsilon_1 - 1}{n\varepsilon_1 + 2} + v_2 \frac{n\varepsilon_2 - 1}{n\varepsilon_2 + 2} + \text{etc.,} \tag{9a}$$

i.e., the dielectric constant of the mixture ε'_m is not in general n times as large as ε_m. This contradicts the easily provable requirement that, retaining the form and increasing the dielectric constants of the components in the same ratio, the dielectric constant of the mixture must also change in the same ratio. This requirement follows from the fact that the lines of force remain the same if the dielectric constant of two neighboring bodies change in the same ratio.††

Wiener,[64, 65, 66] recognizing that formula (9) represents only a special case, undertook to find a general formula which would also take account of the influence of the form of a mixture on its dielectric constant. Two methods were attempted. One consisted of "a repeated approximation which leads to a generally strict solution. The dielectric constant results here in the form of an infinite series which continue according to powers of the

†† Since equation (9) is valid only when $\varepsilon_2 = 1$, we may write it in the form in which it is very often given, *i.e.*,

$$\frac{\varepsilon_m - \varepsilon_2}{\varepsilon_m + 2\varepsilon_2} = v_1 \frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + 2\varepsilon_2}. \tag{10}$$

relative differences of the dielectric constants of the components and whose coefficients consist of several space integrals, which increase with each term about an integral which relates only to the given form of the constituents or the separation of the elements of the constituents. The second consists of the use of a threefold infinite Fourier series, whose coefficients are to be calculated, strictly taken, from infinitely many linear equations with infinitely many unknowns." Since these methods would be very difficult to apply, an attempt was made to get an approximation formula of the form of the Lorenz-Lorentz equation (9). By assuming that the ratio of the mean values of the electric forces are dependent on the form but not on the volume ratios of the components, he obtained the formula

$$\frac{\varepsilon_m - 1}{\varepsilon_m + u} = v_1 \frac{\varepsilon_1 - 1}{\varepsilon_1 + u} + v_2 \frac{\varepsilon_2 - 1}{\varepsilon_2 + u}. \qquad (11)$$

For $u = 2$, this equation becomes identical with (9). When $u = 2\varepsilon_2$, equation (11) takes the same form as (10), indicating that the constituent I is imbedded in constituent II as spheres isotropically arranged at sufficient separation so that the spheres may be regarded as in a homogeneous field. For isotropic arrangements of spheres of one constituent in another u may be regarded as equal to one-half the dielectric constant of the con-

TABLE I.

Arrangement.	u	Formula.	No.
Layers perpendicular to the lines of force.....	0	$\frac{1}{\varepsilon_m} = \frac{v_1}{\varepsilon_1} + \frac{v_2}{\varepsilon_2}$	(12)
Cylinders of I in II $\perp$ to lines of force.....	ε_2	$\frac{\varepsilon_m - \varepsilon_2}{\varepsilon_m + \varepsilon_2} = v_1 \frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + \varepsilon_2}$	(13)
Spheres of I in II.....	$2\varepsilon_2$	$\frac{\varepsilon_m - \varepsilon_2}{\varepsilon_m + 2\varepsilon_2} = v_1 \frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + 2\varepsilon_2}$	(14)
Cylinders of II in I $\perp$ to lines of force.....	ε_1	$\frac{\varepsilon_m - \varepsilon_1}{\varepsilon_m + \varepsilon_1} = v_2 \frac{\varepsilon_2 - \varepsilon_1}{\varepsilon_2 + \varepsilon_1}$	(15)
Spheres of II in I.....	$2\varepsilon_1$	$\frac{\varepsilon_m - \varepsilon_1}{\varepsilon_m + 2\varepsilon_1} = v_2 \frac{\varepsilon_2 - \varepsilon_1}{\varepsilon_2 + 2\varepsilon_1}$	(16)
Layers or discs parallel to lines of force.....	∞	$\varepsilon_m = v_1\varepsilon_1 + v_2\varepsilon_2$	(17)

tinuous phase and should vary, therefore, only between the limits $\frac{1}{2}\varepsilon_2$ and $\frac{1}{2}\varepsilon_1$. Wiener further calculates the values of u for several special cases whereby there result the formulæ giving the relation between ε_m, ε_1, and ε_2 as shown in Table I.

H. Fricke [22] has recently derived a formula which has a very marked similarity to that of Wiener's. Considering the case of spheroids dispersed in a liquid medium, he obtains the relation

$$\frac{\varepsilon_m - \varepsilon_2}{\varepsilon_m + u\varepsilon_2} = v_1 \frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + u\varepsilon_2}, \tag{18}$$

where u is a function of the ratio $\varepsilon_1/\varepsilon_2$ and the ratio a/b of the axis of symmetry of the spheroids to the other axis. u is given by the formula

$$u = -\frac{(\varepsilon_1/\varepsilon_2 - 1) - (\varepsilon_1/\varepsilon_2)\beta}{(\varepsilon_1/\varepsilon_2 - 1) - \beta}, \tag{19}$$

in which the influence of the geometrical factors of the suspended particles is expressed solely in β. Fricke's formula, (18), reduces to that of Lorenz-Lorentz and Clausius-Mossotti for the case of spheres where $u = 2$.

Wiener [66] makes the specific statement that his formula does not apply to chemical mixtures, *i.e.*, mixtures of two liquids. For such cases, Silberstein[55] derived thermodynamically a "proof" of the law of mixtures, assuming no change in volume on mixing and independence of action of the constituents. According to him, "the dielectric constant of a homogeneous mixture which consists of V_1, V_2 . . . V_n c.c. of completely (or very good) insulating dielectric substances A_1, A_2 . . . A_n, respectively, is given by the equation

$$\varepsilon = \frac{\sum_1^n i\, \varepsilon_i V_i}{\sum_1^n i\ V_i} \tag{20}$$

where ε_1, ε_2, . . . ε_n are the dielectric constants of A_1, A_2 . . . A_n at one and the same temperature and pressure, assuming that the volume of the mixture is equal to the sum of the volumes of the constituents, *i.e.*,

$$V = \sum_1^n i\, V_i ." \tag{21}$$

For binary mixtures, using the notation of this paper, formula (20) becomes

$$\varepsilon_m = v_1 \varepsilon_1 + v_2 \varepsilon_2 . \qquad (17)$$

Correction of this formula to take into account the contraction on mixing the two liquids is insufficient to make the equation generally applicable.[27] ‡‡

From the above discussion it is evident that all the formulæ derived for the calculation of the dielectric constant of a mixture of components of known dielectric constants include the two related assumptions, (1) that the capacities are directly additive and (2) that the molecules of the two components have no dielectric influence on each other. Simple consideration of the dipolar nature of most molecules [10] would indicate that these assumptions are probably not justified. Likewise, it will be observed in consideration of the following experimental data that the agreement between the observed values of the dielectric constants of mixtures and those calculated according to these assumptions is best for the cases where both components have low dielectric constants, *i.e.*, small dipolar moments. However, while the data may seem to be in general in qualitative agreement with the considerations of the dipolar nature of most molecules, nevertheless at present there are not enough data on the dipolar moments of the molecules to predict quantitatively the effect on the dielectric constant of adding one substance to another.

B. EXPERIMENTAL RESULTS.

(a) Liquid-liquid Mixtures.—E. Cohn and L. Arons [7] measured the dielectric constants of (1) three mixtures of *aniline* in *xylene,* (2) one mixture of *aniline* and *benzene* but do not give the compositions. They found, however, that successive additions of *aniline* to the *xylene* increased the dielectric constant of the mixture. Later [8] they also determined the dielectric constants of five mixtures of *xylene* and *ethyl alcohol,* containing up to 50 per cent. by volume of the alcohol, and state that "with the first additions of alcohol to pure xylene, the dielectric constant changes very slowly." Similarly they were unable to detect the influence of 2 per cent. of *water* on the dielectric constant of *ethyl alcohol.*

‡‡ It has been shown, in work soon to be published, that the deviation from this simple law of mixtures for dielectric constants is in certain cases directly proportional to the deviation from the analogous law of mixtures for viscosity. In this case of liquid-liquid mixtures, therefore, the form of the curve relating dielectric constant to composition can be predicted from the viscosity composition curve.

These results do not agree very well with those of E. Bouty,[5] who measured the dielectric constants of mixtures of *benzene, turpentine,* and *carbon disulphide* with *ethyl alcohol* and *ether* and found that they satisfactorily followed the simple law of mixtures (formula 17). Likewise, Jahn and Möller,[32] who investigated the dielectric constants of mixtures of *alcohol* and *xylene,* found at moderate concentrations of alcohol a fair agreement between the observed values and those calculated from this law.

Thwing,[59] using a bridge method of measurement and an oscillator giving a frequency of about 2.5×10^7, investigated the dielectric constants of a series of mixtures, especially those aqueous mixtures of such substances as mix in all proportions with water. In the case of the aqueous mixtures of *methyl alcohol, ethyl alcohol, propyl alcohol, glycerin,* and *acetic acid,* the curves relating dielectric constant to concentration all showed one or more singular points (*i.e.,* maxima or peaks) which, without exception, fell at concentrations which exactly correspond to hydrates. In the case of ethyl alcohol and water, there were six such breaks. The curve for mixtures of *ethyl* and *methyl alcohols,* on the other hand, was quite regular, though the values of the dielectric constants of the mixtures always were less than calculated from the law of mixtures. Drude,[13] using a resonance method and a considerably higher frequency, about 4×10^9, failed to find the irregularities in the curves relating the dielectric constant to concentration in the case of mixtures of *methyl alcohol* and *water* and *propionic acid* and water. In these cases, according to Drude, the law of mixtures holds within the experimental error. On the other hand, the law of mixtures gave too great values for the dielectric constants of mixtures of *acetone* and *benzene* and too small for mixtures of *acetone* and *water.* The more recent measurements of Harrington [28] are in agreement with those of Drude, while those of Salazar [53] support qualitatively the data of Thwing. Salazar measured the dielectric constants of mixtures of *water* and *methyl, ethyl* and *propyl alcohols* and found they did not agree with Silberstein's law of mixtures. At 25° there appeared breaks corresponding to hydrates with one, two and three molecules of water and also with sixteen in the case of propyl alcohol. In the intervals between the breaks the dielectric constant was proportional to the composition.

Jahn and Möller [32] also investigated the dielectric constants of mixtures of *xylene*, with *toluene, amyl alcohol, isobutyl alcohol*, and *amyl chloride* and found an approximate agreement between observed values and those calculated from the simple law of mixtures only in the case of the more dilute solutions of the alcohols. At the higher concentrations of alcohol the observed dielectric constant was higher than the calculated. Also for the solutions of amyl chloride the observed value for all concentrations was too great.

Silberstein,[55] on the contrary, found the law of mixtures to give satisfactory agreement between calculated and observed values of the dielectric constant of *benzene* and *phenyl acetate*. C. E. Linebarger [39] confined his attention to mixtures of liquids, of which the constituents all had a dielectric constant less than 8. These were mixtures of *benzene* with *ether, ethyl acetate*, and *carbon tetrachloride; toluene* with *ethyl benzoate, turpentine*, and *carbon disulphide; chloroform* and *carbon tetrachloride;* and *carbon disulphide* with *carbon tetrachloride, chloroform*, and *ether*. In no case did the data show complete agreement with the law of mixtures. The dielectric constant was generally lower than that calculated from the dielectric constants of the components. Mixtures with *ethyl ether* were exceptions and gave higher values than calculated. In the case of *carbon disulphide* and *carbon tetrachloride* there was a point of inflection, but the data were too scarce to determine at what composition this occurred.

J. C. Philip,[48] in an investigation of the dielectric constants of quite an extended series of mixtures, tested the applicability of formula (9), *i.e.*,

$$\frac{\varepsilon_m - 1}{\varepsilon_m + 2} = v_1 \frac{\varepsilon_1 - 1}{\varepsilon_1 + 2} + v_2 \frac{\varepsilon_2 - 1}{\varepsilon_2 + 2}, \tag{9}$$

and one analogously formed from formula (1), *i.e.*,

$$\sqrt{\varepsilon_m} - 1 = v_1 (\sqrt{\varepsilon_1} - 1) + v_2 (\sqrt{\varepsilon_2} - 1). \tag{22}$$

He found that where both components of a binary mixture have a low dielectric constant, either formula gives equally satisfactory results, *i.e.*, with mixtures of *benzene* and *ether*, or *carbon disulphide* and *chloroform*. Mixtures of *ethyl ether* and *chloroform* gave no agreement with either formula and in fact showed higher dielectric constants for the mixtures than for either component alone. Where one of the components had a high dielectric con-

stant, *i.e.*, in mixtures of *ethyl alcohol* with *chloroform, ethyl ether, carbon disulphide,* and *benzene;* and *nitrobenzene* with *benzene,* and *toluene,* the agreement was much better with formula (22) than with (9). The latter formula at times gave calculated values about half of those observed. However, the agreement between the observed values and those calculated from (22) cannot always be designated as satisfactory. In the case of *benzene* and *ethyl* or *propyl alcohol,* with greater concentration of the substance of high dielectric constant, the calculated values are lower than the observed, and at lower concentrations, higher. Using this formula, (22), for calculating the dielectric constants of *methyl, ethyl, propyl* and *amyl alcohol* in *benzene* and *toluene,* and assuming the dielectric constants of benzene and toluene are unchanged in the solutions of low concentration of the alcohols, a lower limit was approached which, according to Philip, represents the dielectric constant of the simple molecule; the higher values of the pure liquids and more concentrated solutions being due to association. The values he obtained are given in Table II.

TABLE II.

Alcohol.	Dielectric Constant.	
	Pure Liquid.	Calculated from Dilute Solutions.
Methyl.....	35.4	16.0
Ethyl.....	26.8	11.0
Propyl.....	22.5	8.5
Amyl.....	16.7	6.0

Similar results have been obtained recently in an investigation by L. Lange,[35] who attributes the deviations from formula (9) to molecular association. The measurements covered five different *alcohols,* as well as *nitrobenzene, pyridine,* and *ether. Benzene* was in general used as the solvent but checks were made using *toluene* and *carbon disulphide* as solvents. In order to explain the results obtained, it was necessary to assume two different types of molecular association having opposite effects on the dielectric polarization. A third type was necessary at higher concentrations.

W. D. Coolidge,[9] with a slightly different experimental method from Philip's, obtained the same numerical values for the lower limits of the dielectric constants of the alcohols as are

given in Table II, indicating that this limit is independent of the frequency. He likewise qualitatively checked Philip as to the presence of a maximum in the curve relating dielectric constant and concentration for mixtures of *ethyl ether* and *chloroform*. In a later investigation, Philip and Haynes [49] calculated the apparent dielectric constants of *anisole, o-, m-,* and *p-tolyl methyl esters, phenol,* and *o-, m-* and *p-creosols,* in dilute solution in *benzene* and *m-xylene,* according to formula (22). From the same line of reasoning as obtained in their first paper, they concluded that the phenols are associated and that the esters are not, which is in agreement with cryoscopic evidence.

Dobroserdov [12] determined the dielectric constants of a very large number of mixtures of organic solvents, such as *benzene, toluene, ethyl ether, chlorobenzene, carbon disulphide,* etc. The original paper, not being accessible, was not consulted. However, according to the abstract, the results of his experiments indicate that none of the formulæ proposed for expressing the relation between the dielectric constant and the composition of such mixtures is in complete accord with the data. He considers that the cases which can be expressed by Silberstein's formula, (17), are the normal ones, while the deviations from the "normal" are to be ascribed to the formation of solvates possessing different properties from the components.

The most recent work on the dielectric constants of liquid mixtures, that of M. Grützmacher,[27] serves only to emphasize the lack of order and understanding which obtains in this field, such as is evident from the above mass of uncorrelated and even contradictory data. Grützmacher measured the dielectric constants at different temperatures of mixtures of *carbon tetrachloride* with *carbon disulphide* and *chloroform;* and *benzene* with *toluene* and *carbon disulphide.* He found that his results also could not be expressed by any previously proposed formula.

(b) Electrolytic Solutions.—Experimental difficulties are much greater in the measurement of the dielectric constants of electrolytic solutions than in the case of mixtures of liquids on account of the fact that they are much better conductors of electricity. In order to minimize the effect of such conduction the measurements must be carried out at very high frequencies. The data on the dielectric constants of electrolytic solutions reported in the literature have largely been obtained incidently to the main

object of the investigation and are therefore rather scanty. The recent work of Walden [61, 62] and his co-workers promises to give interesting data in this relatively uninvestigated field.

E. Cohn and L. Arons [8] state that the addition of *ammonium chloride* to *98 per cent. alcohol* did not affect the dielectric constant within the experimental error of ± 5 per cent., although the conductivity was increased five times.

E. Lecher [38] found the capacity of his condenser to be the same whether a vessel between the plates of the condenser contained distilled water or a 10 per cent. solution of *sulphuric acid*. The condenser plates were 28 cm. apart and the vessel containing the liquid was 27 cm. long. The oscillations used in the measurements were obtained from a Rumkorff coil.

E. Bouty [5] found that the dielectric constant of distilled water was unchanged on adding small amounts of *sodium chloride*. Similarly water taken from the Siene River showed the same dielectric constant as the distilled water.

C. B. Thwing,[59] as reported in section (*a*), measured the dielectric constants of mixtures of *acetic acid* and water and obtained irregularities in the curve relating dielectric constant and concentration, small additions of acetic acid to water, causing at first relatively large decreases in the dielectric constant. P. Drude [13, 14] failed to find any such irregularities in the case of *propionic acid* and water and in case of aqueous solutions of *copper sulphate* and *sodium chloride* the dielectric constants were not different from that of pure water. He states that up to conductivities of 5×10^{-7}, referred to mercury as unity, the dielectric constant of solutions at frequencies of 4×10^{8} is within 1 per cent. that of pure water. At higher conductivities the dielectric constant was determined to be smaller, at least 10 per cent. at a conductivity of 38×10^{-7}.

W. Nernst,[46] using a high frequency in his Wheatstone bridge method of measuring capacity, found that sufficient *potassium chloride* to make a 0.005 N and a 0.01 N solution had little effect on the dielectric constant of water. The dielectric constants were 3 to 5 per cent. higher than that of water for the potassium chloride solutions and about 2 per cent. lower for a 2 : 3 *mannite-boric acid* solution. On the other hand, F. J. Smale,[56] working with Nernst, but using an electrometer method and frequencies from 10^{6} to 10^{7} for determining his dielectric constants found a

considerable increase (up to 15 per cent.) in dielectric constant over that of pure water with solutions of *potassium chloride, hydrochloric acid, copper sulphate* and *mannite-boric acid* solutions, ranging from 0.001 M to 0.666 M. He therefore concludes that "the dielectric constants of good conducting solutions actually increase with increasing concentration, but that this increase is not necessarily proportional to the conductivity."

A. de Forest Palmer, Jr.,[47] also using an electrometer method, determined the dielectric constants of dilute solutions of *potassium chloride* and *copper sulphate* at a maximum concentration of about 0.003 gr. equivalents per litre for copper sulphate. The result of this investigation was the conclusion "that it is highly probable that the dielectric constant of dilute electrolytic solutions, of conductivity less than 2.5×10^{-4}, is the same as that of pure water in electric fields varying at the rate of 10^6 oscillations per second."

Walden,[60] considering that the influence of electrolytes on the dielectric constant of the solvent was quite unsettled, decided to study the influence of electrolytes in solvents of weaker ionizing power than water. For this purpose, he choose the three solvents, *chloroform* ($\varepsilon = 4.95$), *methylene chloride* ($\varepsilon = 8.3$) and *ethyl formate* ($\varepsilon = 8.2$) and for electrolytes several salts of various substituted *ammonium bases.* For measuring capacity he used Drude's resonance method. He found in every case that the dielectric constant of the solution was greater than that of the solvent. For a given dilution, he found that the percentage increase in dielectric was greatest for the tetra-substituted electrolytes and also greatest in the solvent of lowest dielectric constant (*i.e.,* chloroform). However, the increase was scarcely above the experimental error in the case of the mono- and di-substituted ammonium salts. Without considering the applicability of the formulæ to the experimental data at hand, Walden calculated values for the dielectric constants of the salts, using formulæ (17) and (22) and one used by Bouty.[5] The values so obtained were very high and depended not only on the particular formula used, but also on the concentration chosen. For instance, calculated from formula (17), the dielectric constant of tetraethyl ammonium iodide in methylene chloride is given as 330, while from formula (22) the value of 3250 is obtained. Similar results are given for the other cases studied.

On the other hand, Lattey,[36] also using Drude's method, modified so as to allow for correction due to electrolytic conduction, found a very considerable lowering of the dielectric constant of aqueous solutions of *potassium chloride, copper sulphate,* and *tetraethyl ammonium naphthalene-β-sulphonate* on successive additions of the salt to pure water. For a 0.00755 M potassium chloride solution, he found the value of the dielectric constant to be only 66.25 or only 81.5 per cent. that of pure water. The results on the other salts were quite comparable.

Within the past two years Blüh,[3] Fürth,[24] and Walden and Ulrich [61, 62] have begun a more thorough investigation of the dielectric constants of electrolytic solutions both from a theoretical and experimental viewpoint. Blüh, in agreement with the Debye theory of dielectrics, assumes that the deviations from the law of mixtures observed with electrolytic solutions are due to hydration of the ions. According to this assumption each ion is surrounded by a definite layer of water molecules, which, owing to their dipolar character, are oriented under the influence of the charged ion. Assigning a value of unity to this water of hydration and calculating its volume from the values of the real and apparent radii given by Born,|||| Blüh finds that the experimental values of Sommer (unpublished dissertation, Berlin, 1923) on solutions of *lithium, sodium,* and *potassium chlorides* are in satisfactory agreement with the law of mixtures. However, while both experimental and calculated data show a linear relationship between the dielectric constant and concentration, the theoretical and observed values are not in quantitative agreement.

The measurements of Fürth [24] on solutions of *sodium chloride* have shown that while at high concentrations of salt the dielectric constant of the solution approaches that of pure water, for very small concentrations the dielectric constant of the solution is lowered by an amount which is dependent on the potential across the condenser. Since these data were obtained at a very low frequency, *i.e.*, 50 cycles, it is doubtful to what extent the discordant results obtained by earlier investigators may be accounted for by this effect. Fürth is in agreement with Blüh in explaining the dependence of the dielectric constant of the solution on concentration as due to the orienting effect of the ions on the water dipoles. The fact that the curve relating the dielectric constant

|||| *Z. Physik,* 1, 221, 1920.

of the solutions to concentration passes through a minimum, approaching the value of water at the higher concentrations, is explained by the fact that at these higher concentrations there is greater competition among the ions for the water of hydration and consequently the thickness of the water layer surrounding the ions decreases.

Walden, Ulrich, and Werner [62] have shown that an explanation similar to that proposed by Blüh and Fürth, qualitatively satisfies the large mass of experimental data obtained by them on solutions of *tetrapropylammonium iodide* and *tetraethylammonium picrate* in *chloroform, brombenzene, chlorbenzene, ethylaniline, technical aniline, o-dichlorbenzene, sym-tetrachlorethane, ethylene chloride, pyridin, m-nitrotoluol,* and *water*. Their measurements also include data on aqueous solutions of *potassium chloride* and *cadmium bromide*. These observations show further, as would be expected from the Debye theory of dielectrics, that the lowering of the dielectric constant is proportionately greater (molecular concentration being constant) in the solvents of lower dielectric constants for a given salt and also greater in a given solvent for the smaller ions. In general the curves relating dielectric constant to concentration pass through a minimum, though in certain cases the minimum presumably occurred at concentrations greater than could be obtained at the temperature of the experiments. It was further found that the influence of impurities in the solvents was of considerable importance and necessitated the repetition of a considerable amount of experimental work. The effect of these impurities was largely to mask the minimum in the concentration curve.

From this later work on electrolytic solutions, one may see that the general behavior of this class of mixtures can be qualitatively predicted from a consideration of the Debye theory of dielectrics. As yet, however, the theory has not been sufficiently developed to allow a satisfactory quantitative agreement between theory and experiment.

(c) Non-electrolytic Solutions.—In this section there will be included a discussion of the measurements on solutions generally regarded to be non-electrolytic and *not* colloidal. The transition from this section to that on colloidal solutions is necessarily not abrupt and the classification will have to be to a certain extent arbitrary.

The dielectric constants of aqueous solutions of *cane sugar* have been measured by four independent investigators, P. Drude,[13, 14] E. A. Harrington,[28] R. T. Lattey[36] and R. Fürth.[23] The results of Drude, Harrington and Lattey are in satisfactory agreement, where they can be compared, and are qualitatively the same as those of Fürth. Although the dielectric constants of aqueous solutions of cane sugar do not follow the simple law of mixtures, the values of the solutions at all concentrations (up to 65 per cent.) lie between those of the solid cane sugar (4.9 ± 0.2)[23] and pure water. On the other hand, according to Mathews,[44] the addition of 6.47 per cent. *cane sugar* to *pyridine* ($\varepsilon = 12.5$) raises the dielectric constant to 13.5.

H. E. Eggers,[16] using Drude's resonance method of measuring capacity, determined the dielectric constants of solutions of *sulphur* and *phosphorus* in *carbon disulphide; menthol* in *benzene, carbon disulphide,* and *acetonitrile;* and *camphor* in *benzene* and *carbon disulphide.* He found the dielectric constant of the solution of sulphur in carbon disulphide alone to lie between the values of the pure components. In the cases where several solvents were used for the same solute, the values of the dielectric constants obtained did not indicate that the solute exerted a similar influence in each case. This is in agreement with other data which indicates that the dielectric constant of a solution is not a simple function of either constituent.

L. Kahlenberg and R. B. Anthony,[34] who measured the dielectric constants of solutions of the *oleates* of *magnesium, aluminum, zinc, manganese, nickel, cobalt, iron, copper,* and *cadmium,* in several solvents found the dielectric constant to be generally lowered on the addition of the oleate. However, the change in dielectric constant was generally small, even for high concentrations, and the effect of the metal was entirely masked.

Probably the most extensive investigation of the dielectric constants of aqueous solutions of non-electrolytes is that recently reported by R. Fürth.[23] He used Drude's resonance method of measuring capacities and used a Tesla coil as his source of frequency. His measurements include the dielectric constants of aqueous solutions of *dextrose, levulose, cane sugar, saccharin, urea,* and *glycocoll.* The dielectric constants of the solutions of the sugars were always less than that of water, those of solutions of glycocoll and urea always more, while the dielectric constants of

solutions of saccharin increased to a maximum at about 0.3 per cent. saccharin and then very rapidly decreased. The results on solutions of urea are qualitatively in agreement with the earlier data of Harrington.[28] The significance of these three types of behavior is discussed from the standpoint of Debye's theory of dielectrics in alternating fields.[11] According to this theory, if the dipolar moment of the solute is greater for unit volume than that of the solvent, increase in concentration of the solute will result in increase in the dielectric constant of the solution. However, the viscosity also increases with the concentration and tends to decrease the dielectric constant. These two factors therefore cause first a rapid increase in the dielectric constant and then a slower increase to a maximum, and finally an increasingly rapid decrease. The position of the maximum with reference to concentration will vary with the magnitude of the dipolar moment and the viscosity. In case the maximum falls on zero concentration, the curve relating dielectric constant to concentration will continually decrease (Type I)—the same type is obtained in case the dipolar moment of the solute is less than that of the solvent; in case the maximum is located at saturation, one obtains a continually increasing curve (Type II); and in case the maximum occurs at some intermediate concentration one obtains a point of inflection (Type III). Fürth's data afford examples of all three types; the sugars belong to Type I, glycocoll and urea to Type II, and saccharin to Type III.

(d) Colloidal Solutions.—The data available on the dielectric constants of colloidal solutions leave much to be desired. Not only are the data meagre, but where measurements are given the concentration is very uncertain and even in some cases the exact composition is unknown, *i.e.*, serums and solutions of biological interest as reported by Fürth.[23]

Drude [14] stated that *gelatine* gels gave values of dielectric constant very little different from that of pure water. On the other hand, Fürth,[23] who studied gelatine solutions up to 50 per cent. gelatine in concentration, found that gelatine gave a curve belonging to Type I, showing a relatively rapid decrease at low concentrations. *Albumin,* in concentrations up to 15 per cent., showed a behavior very similar to that of gelatine. *Lecithin* and *pepsin* both decreased while *trypsin* increased the dielectric constant of water.

J. Errera [17, 18, 19, 20, 21] has measured the dielectric constants of several inorganic sols. These include *mercuric sulphide-alcosol, copper sulphide-alcosol, platinum-alcosol,* and *vanadium pentoxide hydro-sol.* His measurements indicate that the colloidal solutions studied have the same dielectric constant as the pure solvent with the exception of vanadium pentoxide sols. The dielectric constants of these sols were variable, decreasing with the temperature and with the frequency, but increasing with the intensity of the field. The decrease with frequency is almost linear from a wave-length $\lambda = 1000$ to $\lambda = 300$ metres. The observed dielectric constant increased during measurement and depends on the concentration. Although the values of the dielectric constant recorded ranged from 81 for pure water up to 800, depending on the experimental conditions, Errera states that a comparison with the dielectric constants of electrolytic solutions of similar conductivity indicates that the observed high dielectric constants of the vanadium pentoxide sols do not seem to be due to an actually higher conductivity factor.

Fürth and Blüh [25] have studied the dielectric constants of vanadium pentoxide sols at a much higher frequency, *i.e.,* a wave-length of 70 cm. At this frequency a sol three years old showed an increase in dielectric constant with increase in concentration, while the converse was found to be the case in a freshly prepared solution. In general, their results are in accord with those of Errera. They indicate, however, that Errera is wrong in supposing that the dielectric constant increases with the field strength, E. It is the polarization, P, which increases, where $P = \frac{\varepsilon - 1}{4\pi} E$. The observations of Errera are attributed to simple polarization of the electrodes.

(e) Mixtures Showing a High Degree of Heterogeneity.—Eight investigations may be included in this section. Of these, the first four were undertaken to test experimentally the Clausius-Mossotti relationship in the form given by Lorentz for mixtures in equation (9). The second group of investigations were undertaken primarily for a test of Wiener's formula, *i.e.,* (11), and to evaluate the constant u for different experimental conditions.

The studies undertaken by the first four investigators are very similar in that measurements were made on mixtures of a material of relatively low dielectric constant with another material

having such a relatively high dielectric constant that for practical purposes it might be considered infinite. In this case, the equation,

$$\frac{\varepsilon_m - 1}{\varepsilon_m + 2} = v_1 \frac{\varepsilon_1 - 1}{\varepsilon_1 + 2} + v_2 \frac{\varepsilon_2 - 1}{\varepsilon_2 + 2}, \tag{9}$$

may be simplified since the second term on the right-hand side becomes equal to v_2; and then, since $v_1 + v_2 = 1$, (9) may be transformed to

$$\varepsilon_m = \frac{\varepsilon_1 + 2v_2}{1 - v_2} \tag{23}$$

or, if v_2 is so small that $2v_2\varepsilon_1$ may be neglected with respect to ε_1,

$$\varepsilon_m/\varepsilon_1 = \frac{1 + 2v_2}{1 - v_2}. \tag{23'}$$

Millikan [45] tested the relationship given by (23') by determining the ratio $\varepsilon_m/\varepsilon_1$ for emulsions of water in a mixture of benzene and carbon tetrachloride having a density of 1. The measurements were made by use of Nernst's method. It may be noted that in order to apply (23') the assumption had to be made that the dielectric constant of water is infinitely great compared with that of the mixture. Agreement between observed and calculated values of the ratio $\varepsilon_m/\varepsilon_1$ was on the average considerably better than 1 per cent. However, since v_2 ranged from about 0.03 to 0.14, the difference in values calculated from the exact relationship (23) and the approximate one (23') would be considerably greater, *i.e.*, on the average (23) would have given values about 10 per cent. lower than the observed ratios of $\varepsilon_m/\varepsilon_1$ if ε_1 is assumed to have had a value of 3. Further, since $\frac{\varepsilon_2 - 1}{\varepsilon_2 + 2}$ for water is not equal to 1 but to about 0.97, the calculated values should be an additional 3 per cent. lower on this account.

The same criticism may be applied to the work of Beaulard,[2] who determined the ratio of $\varepsilon_m/\varepsilon_1$ for two condensers made with dielectrics of paraffin and copper dust, with $v_2 = 0.06904$ and 0.01607. The experimental values were on the average 3 per cent. higher than those calculated from (23') instead of 5 per cent. lower as would be expected if the data accurately fit the exact relationship (23).

Hwlawti [29] observes that the work of Millikan and Beaulard did not meet satisfactorily the condition, assumed in the development of the Clausius-Mossotti relationship, of spherical particles

of a perfect conductor imbedded in the insulating medium. He therefore prepared a series of salves containing mercury and obtains results which are not in agreement with (23) but in which ε_m is a linear function of v_2. In these measurements, ε_1 and ε_m were determined by use of Nernst's method of measurement, v_2 ranged from 0.002 to 0.035, the diameter of the particles of mercury ranged from 0.00296 to 0.00346 mm., and the separation of the particle centres from 0.00729 to 0.01963 mm. Hwlawti states that Boccara and Gandolfi [4] found a similar linear relationship between ε_m and v_2 with mixtures of iron dust and paraffin, using Hertzian waves.

Between these experimental tests of the Clausius-Mossotti relationship and those of Wiener's formula, approximately ten years elapsed. The first of this second set of investigations was carried out by Ficker (unpublished dissertation, Wiener [65]), who determined the dielectric constants of several mixtures of hard rubber ($\varepsilon_1 = 2.8$) and air ($\varepsilon_2 = 1$) and from the results calculated the values for u. The data, taken from Wiener's paper, are given in Table III.

TABLE III.

Form and Arrangement.	V_1	ε_1	ε_m (obs.)	u (cal.)
Spheres, close packed.....	0.526	2.801	1.722 1.732	1.7 1.9
Hollow spheres, close packed	0.238	2.801	1.323 1.325	3.2 3.3
Cubes, widely separated	0.125	2.813	1.150 1.153	2.1 2.3
Cubes, closely packed	0.500	2.813	1.727 1.732	2.7 2.8
Prisms, isotropic.....	0.483	2.813	1.720 1.740	3.3 4.1

By inspection of the figures given in Table III, it is readily seen how sensitive u is to small changes in the observed value of ε_m. Simple calculation shows similarly that, assuming a value of u and attempting to calculate ε_1 from the observed value of ε_m, the value so obtained for ε_1 is very sensitive to the value of u chosen. For example, taking $u = 4$ in the last case, *i.e.*, that of prisms isotropically arranged, and using the observed value of $\varepsilon_m = 1.720$, ε_1 may be calculated to be equal to 2.5 in place of

2.8 as given. However, the results given are in qualitative agreement with Wiener's formula. For the more moderate concentration of cubes, for example, the more nearly does the value of u approach the value 2. Likewise, the more the form of the bodies departs from spherical, the higher the value of u.

John [33] also studied mixtures of air and solid bodies of known concentration and arrangement. Again, also, ε_m was measured and u calculated. He chose for his solids, spheres of brass ($\varepsilon_1 = \infty$) and of a mixture of colophonium, wax, and aluminum powder ($\varepsilon_1 = 12.54$), and cubes of brass and of hard rubber ($\varepsilon_1 = 2.863$). He used a guard ring condenser and concentrations of 0.05 to 0.8. On account of the fact that the size of the bodies and condenser were such that John was able to arrange only 84 to 821 bodies between the two plates of his condenser, there is a certain question as to the general applicability of his conclusions. His results may be briefly given as follows: It was found that u was different for spheres and cubes and depended to a considerable extent on the concentration. For *spheres* at relatively great separations u assumed a value of 2, in accordance with the Lorenz-Lorentz formula, and showed a gradual increase with concentration. For moderate concentrations the values of u agreed with the values calculated from the approximation formula of Rayleigh (6), but did not at the closest packing. For *cubes*, u decreased with increasing concentration, reaching the value 2 at about $v_1 = 0.5$, which was shown to be approximately in accordance with the theory. The brass cubes appeared to satisfy the requirements of the theory within the limits of error, but the cubes of hard rubber showed a rise in the values of u with the densest packing which was assumed to be due to experimental error.

Banneitz [1] limited his investigation to testing formula (13), *i.e.*, the case of cylinders arranged perpendicular to the lines of force. He measured his capacity by means of a resonance method. For cylinders he chose glass tubes filled with water and immersed in a mixture of aniline and benzene which had the same dielectric constant as that of the glass. There is here the same limitation as to the validity of his conclusions as applied to John's work, *i.e.*, the number of tubes used was very small, ranging only from 25 to 37. His measurements were made at only three con-

centrations. For great separation of the cylinders from each other (*i.e.*, 12 mm.), the determined value of u was equal to ε_2 in accordance with the theory. For denser packing, however, the deviation from ε_2 was considerably greater than the experimental error.

Since the value of u obtained on a powder of a substance crystallizing in the regular system should apply to all substances crystallizing in the same system, Stoecker [57] investigated the dielectric constants of mixtures of powdered potassium chloride ($\varepsilon = 4.79$) and air. He used the resonance method of measuring capacity and a frequency of about 6×10^7. He sorted the potassium chloride into different size classes and measured the dielectric constant at several concentrations. For the unpowdered salt (length of edge $= L = 1$ to 5 mm.) ε_m and u were greater, the greater the value of L and the denser the packing. For sufficiently fine powders ($L = 0.1$ to 0.6 mm.) ε_m and u were independent of the size as shown by measurements on five classes of the powder, but dependent on the concentration. The values of u obtained for the finer powders at different concentrations are given in Table IV.

TABLE IV.

v_1	ε_m	u
0.30	1.64_8	2.5_1
0.40	1.94_0	$2.7_1 \pm 0.4_0$
0.45	2.10_2	2.8_1
0.50	2.27_7	$2.9_1 \pm 0.3_7$
0.55	2.46_4	3.0_2
0.60	2.66_2	3.1_2
0.65	2.87_6	$3.2_4 \pm 0.3_9$
0.70	3.10_4	3.3_8
0 80	3.60_2	3.5_9
1.00 (ext.)	4.79_0	4.0_8

From this brief review of the applicability of Wiener's formula to systems showing a high degree of heterogeneity, it seems clear that, although the experimental evidence is qualitatively in accord with the theory, for each particular case there must be a value of u which cannot be accurately evaluated without prior knowledge of the values of ε_m, ε_1, ε_2, and v_1. Hence the theory is not sufficiently developed to allow the calculation of the dielec-

tric constant of one component in such a system knowing the dielectric constants of the mixture and the other component. For determining the dielectric constant of a powder, therefore, the only satisfactory method is the substitution method described by Schmidt.[54]

C. SUMMARY.

The above review of the experimental data on the dielectric constants of mixtures shows that the dielectric constant of a mixture cannot in general be calculated from the dielectric constants of the components.

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Citrus By-products Industry the Result of Scientific Research. (U. S. Department of Agriculture, Press Service.)—Citrus growers in California continue to develop facilities for utilizing cull oranges and lemons. A few weeks ago a new plant for recovering usable substances from oranges was formally opened at Ontario, Calif.

A dozen years ago great quantities of oranges and lemons not only were discarded as cull fruit, but had to be hauled away at a cost of at least $1 a ton. To-day practically all of this sub-standard fruit is being utilized in numerous ways, returning to the growers an average of $12 or more a ton.

The remarkable growth of the citrus by-products industry which has been developed within the last decade is founded on results of scientific research. Investigations begun about twelve years ago by the Bureau of Chemistry, United States Department of Agriculture, in its branch laboratory at Los Angeles, have resulted in the development of processes for recovering citric acid, as well as other valuable substances such as oil, pectin, juice, and pulp, from oranges and lemons. The commercial application of these processes not only enables the industry to save the fruit that is for one reason or another undesirable for market, but to use marketable fruit at a profit when there is a surplus. It is estimated that 30 per cent. of the annual production is classed as culls, and the prosperity of the citrus growers depends upon a profitable utilization of this unmarketable fruit.

Citrus growers themselves are now operating two by-products plants, one for lemons at Corona, Calif., and the one for oranges at Ontario, Calif. Commercial concerns are now manufacturing on a profitable scale numerous marketable products from large quantities of cull fruit that would otherwise be a loss to the industry.

One plant last year manufactured approximately 2,000,000 pounds of citric acid, using about 40,000 tons of cull lemons, which returned to the growers a net total of about $450,000. Another plant produced about 65,000 pounds of lemon oil with a value of approximately $70,000, as well as 30,000 pounds of pectin.

From waste oranges are manufactured juice, marmalade, pectin, orange oil, and other products. One plant, which used last year

10,000 tons of oranges, put out, among other products, about 50,000 pounds of orange oil having a wholesale value of approximately $100,000.

One concern has even found a profitable outlet for orange pulp from which the juice has been extracted. The disposal of pulp was once a distinct problem, costing the concern about $800 a month. It is now prepared as a feed for dairy cattle and sold as wet pulp for about $3 a ton. The handling of this product instead of being a monthly liability of $800 now returns the concern a profit of from $2500 to $3000 a month.

The research laboratory at Los Angeles made considerable progress last year in studies to determine the exact chemical differences between the oils made from California fruit and those made from European oranges and lemons. The results of this investigation should show the relative values of the oils for certain uses, such as the manufacture of ice creams, hard candies, cake icings, perfumery, and beverages.

By means of an improved machine to press the oil from orange and lemon peel developed during the past year, at least five pounds of oil can be pressed from the peels of a ton of lemons. One concern in Los Angeles uses 60 tons of citrus fruit a day in making juice by means of a revolving burr-type machine. As citrus oils are worth approximately $2.50 a pound, the extraction and utilization of the oil would mean an additional return of $12.50 for each ton of cull fruit, or on the output of this one plant, a gross additional income of $750 a day. More work must be done to perfect the machine, however, before it can be commercially applied.

It is believed that the research work now under way will enable California manufacturing concerns to utilize these oils from orange and lemon peel for all purposes for which the European oils can now be used.

How Crops Prevent Erosion Shown by Tests. (*Popular Mechanics*, March, 1927, p. 375.)—Interesting demonstrations illustrating how crops prevent the soil from wearing away, have been conducted at the Missouri Experiment Station. The test field was a small plot with a slope equivalent to 3.68 inches to each 100 feet. Under average rainfall of 35.87 inches, it was shown, by collecting the run-off in tanks and weighing the sediment that ran off, a cultivated field without a crop would wear away at the rate of forty-one tons to the acre each year. That meant that it would take but twenty-four years to remove seven inches of surface soil over the entire acre. Sod land lost but .28 ton of dirt per acre each year. Where wheat was grown continuously, the loss was 6.6 tons, a corn plot was reduced by 17.8 tons, while a rotation of corn, wheat and clover lost only 2.3 tons to the acre, showing that an alternating system of planting not only prevents too rapid depletion of the soil in richness but reduces its erosion.

FORMAL PRESENTATION OF A PORTRAIT OF DR. COLEMAN SELLERS TO THE FRANKLIN INSTITUTE.

SPECIAL exercises were held to celebrate the formal presentation to The Franklin Institute of a portrait of Dr. Coleman Sellers, a long-time member of the Institute, a member of the Board of Managers from 1862 to 1905, and President from 1870 to 1874.

The portrait was donated to the Institute by Mrs. S. W. Colton, Jr., of Bryn Mawr, Penna., the daughter of Doctor Sellers, who had the portrait painted by William John Whittemore, of New York City, especially for The Franklin Institute.

The meeting was presided over by Dr. Wm. C. L. Eglin, President of the Institute. He announced that the meeting had been called to receive the portrait of Dr. Coleman Sellers, which was presented by his daughter, Mrs. S. W. Colton, Jr., and that the formal presentation would be made in her behalf by her brother, Mr. Horace Wells Sellers.

Mr. Sellers made the following presentation remarks:

Mr. President: For nearly half a century, almost throughout his entire professional career, Coleman Sellers, Sr., maintained his interest in the objects and activities of this Institute. He was for four terms its president, for many consecutive years, one of its Board of Managers, a frequent contributor to its proceedings and to the work of its committees. He had an interest that was in due measure and in turn sustained by his son, the late Coleman Sellers, Jr.

There was an earlier though indirect association, but one that Doctor Sellers liked to recall, when in his boyhood he was a pupil of Prof. James P. Espy, whose school was on the upper floor of this building.

In token of these associations, it is, Mr. President, my privilege, on behalf of the donor, to present to The Franklin Institute, this portrait of Coleman Sellers, Doctor of Science, Doctor of Engineering, the gift of his daughter, Mrs. Sabin W. Colton, Jr.

In accepting the portrait for the Institute, Doctor Eglin said:

On behalf of the Institute, and representing its Board of Managers, it is a great pleasure to me to accept this portrait. We of the Institute feel that the possession of this portrait will keep before us the high ideals and inspirations which Dr. Coleman Sellers gave so freely during his life. Dr. Coleman Sellers was not only President, but also occupied the Chair of Professor of Mechanical Engineering during the life of the school. I desire to express to Mrs. Colton our sincere thanks for presenting this very handsome portrait.

The President then introduced the speaker of the occasion, Dr. Lewis B. Stillwell:

We are fortunate in having with us to-day an associate of Doctor Sellers in his work with the Niagara Falls Power Company. Doctor Sellers was President and Chief Engineer of that company, and I now present Doctor Stillwell, who was associated with Doctor Sellers as Electrical Director of that company. He will be able to tell us some of Doctor Sellers' work outside the Institute.

Doctor Stillwell read the following paper:

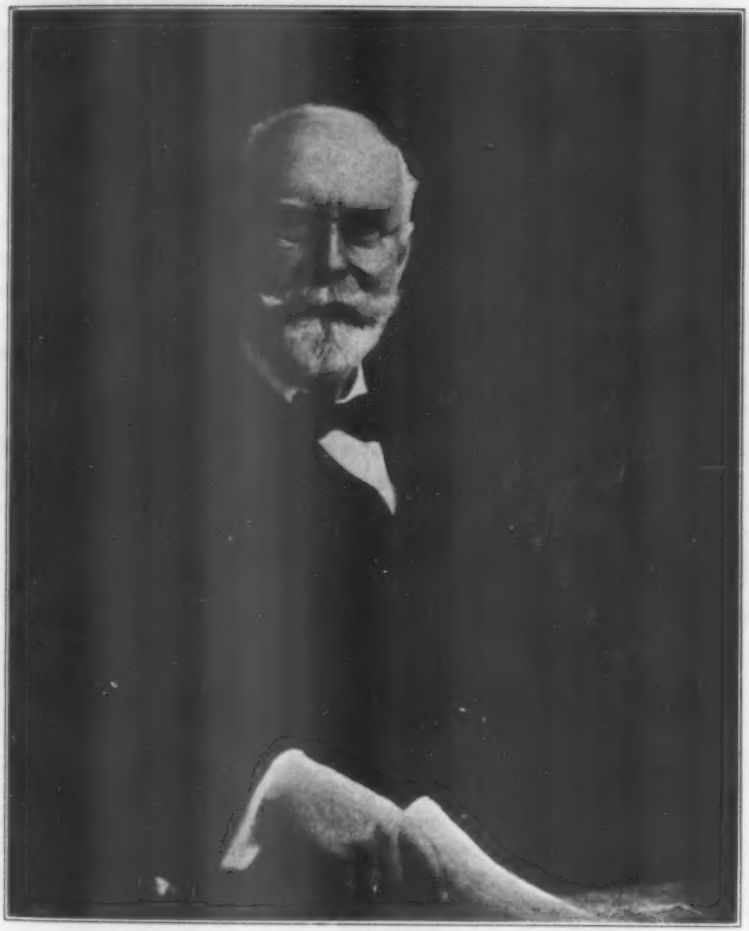
DR. COLEMAN SELLERS.

It is eminently appropriate that a portrait of Dr. Coleman Sellers should occupy an honored position in the hall of The Franklin Institute of Philadelphia.

Sprung from a family distinguished for its contributions to science and the mechanic arts, he became one of the really great contributors to progress in that field which the Institute was founded to encourage and, since its founding, has consistently and effectively promoted.

In 1856, at the age of twenty-nine, returning from a ten-year period of intense activity in Cincinnati, he became one of the most active and useful members of the Institute, serving on numerous committees and contributing papers, discussions and lectures. For several years he was Vice-president and for four successive years President. For more than forty years he was a member of the Board of Managers. From time to time he was active in organizing and managing public exhibitions under the auspices of the Institute, notably that of 1874.

The speaker's personal knowledge of Doctor Sellers' work as an engineer begins in 1890, when the latter began his study of the



COLEMAN SELLERS
1827–1907

problem of the development of power at Niagara Falls. At that time he was sixty-three years of age and for upwards of forty years had been making important contributions to engineering progress. It is a remarkable fact that at a period of life when most men are ready to reduce their obligations and activities, he undertook a problem of extraordinary magnitude and importance in an uncharted field. His contributions to the solution of that problem, now universally recognized as sound, justify the statement that this work was the crowning achievement of his great career as an engineer.

Within the time available, it is possible only to sketch in merest outline his activities prior to his connection with the Niagara enterprise. My information regarding those activities is derived chiefly from an article by the late Dr. Henry Morton, President of Stevens Institute, published in *Cassier's Magazine*, in August, 1893.

Born at Philadelphia on January 28, 1827, he was educated at private schools in that city and at Bolmar's Academy, West Chester, Penna. As a boy, he evinced great interest and aptitude in the field of natural philosophy. While a student at the academy at West Chester, at the age of fifteen, he kept a diary in which the following passages are significant of the trend of his mind at that early age:

"Nov. 3rd, Thursday, 1842.

"Began to make a hygrometer; it is made of catgut on which the atmosphere acts, expanding and contracting it, thus moving an index which shows the degrees on a plate. I have been thinking of making one of a piece of ash, which, by expanding and contracting, works compound levers which are joined to the index; thus, by a slight difference in the wood, a great difference will be perceived in the position of the index; it is to be made pretty much on the same principle as those instruments which show the expansive power of metals, only instead of metal a piece of ash is used in the body to be expanded, and instead of being acted upon by the heat it is to be acted upon by the atmosphere."

"Nov. 4th, Friday.

"At work at my hygrometer, but could not complete it for want of tools. Made an improvement in the instrument; instead of having a weight fastened to the catgut, I intend to put a spring. The benefit of this is that the instrument will work in any position when, if there was weight fastened to the spring, it could only work when in a perpendicular position."

"Nov. 8th, Tuesday.

"Did my first sums in trigonometry to-day; find it pretty easy. Began to read Waverly by Walter Scott. Began to make a machine to show that a weight dropped from the mast of a vessel while in motion will take a diagonal direction in its descent and fall at the foot of the mast."

Regarding his mental activity as a boy, Doctor Morton, in the article to which I have referred, remarks:

"His intense longing at this time for information in natural history, natural philosophy, and chemistry, was not satisfied by the lectures that were delivered to the scholars by a local doctor of medicine. Wanting the assistance of the best text-books, he was compelled to pursue, unaided, such studies as botany and mineralogy, while to gain all the possible good from the meagre lectures on physics and chemistry, he spent, as the quotations from his diary indicate, much of his spare time in making apparatus to illustrate the facts and theories imperfectly taught in the lecture room."

He completed his course at Bolmar's Academy in his seventeenth year and, due to parental solicitude for his health, devoted the next two years to practical agriculture. Here his mechanical bent again asserted itself and among other devices he "contrived and drew a metal-toothed hay rake, mounted on wheels, which antedated the machine now so generally used, but then unheard of."

In 1846, at the age of nineteen, he entered the service of the Globe Rolling Mill, in Cincinnati, Ohio, operated by his elder brothers, Charles and George Escol Sellers. Here he was employed in designing improved mill machinery and acquired knowledge of the processes incident to rolling merchant iron, iron rods, telegraph wire and the flat rails used at that time on railroads of the West.

He became interested in botany, mineralogy and conchology. The lime-stone rocks around Cincinnati were rich in small fossils, and it is said that his collection included many perfect specimens. He procured a few battery cells as used in the telegraph outfits of that time and utilized his spare time in repeating the electrical experiments that had been announced by Faraday and others, making for himself the apparatus required.

Before Doctor Sellers was twenty-one years of age, he was Superintendent and Manager of the Globe Rolling Mills, and in 1851 he was building locomotives invented by one of his elder

brothers for use on the Panama Railroad. Next, he became foreman of the locomotive works of James and Jonathan Niles, in Cincinnati, and his improvements in machine tools, in this connection, led to an offer from his kinsmen, William Sellers and Company, of Philadelphia, in 1856, to take charge of their drafting room. "His experience as a locomotive builder had strongly impressed him with the demand that then existed for better machine tools to reduce the cost of locomotives and improve the quality of the work, particularly the need of special tools designed for that service, and he found in his new business ample opportunity to work out his ideas and further develop and apply his ability as an engineer and inventor."

He retained his position with William Sellers and Company, as chief engineer and as a member of the firm, for over thirty years, extending his experience over a wide field, embracing not only machine tools, but a great variety of hydraulic machinery, cranes, hoists and elevators, presses and forging machines, engines, pumps and injectors, turn-tables and pivot-bridges, and much else.

Doctor Morton, an unquestioned authority, says that his work at that time was characterized by originality, correct mechanical design and unusual elegance of outline. A large number of patented inventions are credited to him. Among these, the double-cone coupling for shafts, a highly successful substitute for the flange, or plate, coupling previously used, became widely known and extensively adopted. It effected a radical change in the manufacture of shafting, cheapening the cost of production and greatly facilitating installation and repair.

Aside from his manifold duties as Chief Engineer of William Sellers and Company, Doctor Sellers found time for much work of a scientific character. He was one of the first, if not the first, to employ the then new art of photography to illustrate machinery for advertising purposes. This was in 1858 and as the results obtained by the portrait photographers at first employed were not satisfactory, he personally learned the process and a photographic dark room was soon established as a regular adjunct of the drafting room. He became greatly interested also in portrait and landscape work and for many years this became his most absorbing avocation. He was one of the founders of the Philadelphia Photographic Society and a prominent member of the Amateur

Exchange Club, founded in 1861 by Mr. H. T. Anthony, of New York.

Among other inventions relating to photography, Doctor Sellers made and patented, in 1861, a device which he called the kinematoscope for the exhibition of stereoscopic pictures of objects in motion, which instrument he considered particularly desirable for illustrating machinery in action. This was a crude prototype of the cinematograph. As shown by his patent drawing, he contemplated also the use of an endless belt approximating more closely the modern highly developed machine.

In the development and extension of technical education in America, The Franklin Institute was a pioneer and in this great constructive work Doctor Sellers was especially interested and active, not only in the work of the Institute, but through other channels. For many years, he delivered frequent lectures at the Stevens Institute, in Hoboken, lectures which undoubtedly influenced many men who since that time have made important contributions to the development of our natural resources through the mechanic arts. In the earlier days of the long battle between the advocates of the metric system and its opponents, he was a striking figure and an effective champion of the English system of measurements, his keen mind and long, practical experience combining to make him one of the most influential opponents of an enforced introduction of the metric system.

Throughout his long and active life, his keen mind and tireless energy brought to bear upon the practical problems which he faced as an engineer the aid of science in various fields. I have said that he employed photography as an aid in advertising. He used the microscope to investigate boiler scale. He introduced electric signalling for communication between the several departments of his company's extensive establishment and himself became a skilled operator. He acquired considerable facility in the use of short-hand. During the period of his intensely active connection with the Niagara Falls power enterprise, in which it was my great privilege to be in close contact with him, the intensity of his mental concentration upon each problem as it arose was equalled only by the ingenuity and variety of methods of attack and of solution which his broad knowledge and his imagination, as well as his wide practical experience, suggested. From personal knowledge, I can testify that Doctor Morton in no way exaggerated

when he said regarding Doctor Sellers: "As the result of personal observation extending over many years and facilitated by the most intimate acquaintance, the writer does not hesitate to say that Doctor Sellers furnishes a most striking illustration of intellectual power unconfined by the limitations of any single subject, or class of subjects, but reaching out into countless directions. In great things, or little, to whatever subject he turns his attention, he masters it with astonishing rapidity and completeness."

I first met Doctor Sellers in the summer of 1890 in London. As engineering adviser to the Cataract Construction Company, then recently organized, he and Mr. Edward D. Adams, the president of that company, were investigating the development and utilization of hydraulic power in Europe. They spent several weeks in London and invited a number of engineers from time to time to meet them to discuss the subject. I happened to be in London at the time and, with Mr. Reginald Belfield, electrician of the British Westinghouse Electric Company, Ltd., was invited by Mr. Adams to meet Doctor Sellers and himself at Brown's Hotel, in Dover Street.

At the outstart, I was greatly impressed by Doctor Sellers' attractive personality and keenness of mind. At that time, as I have said, he was sixty-three years of age, but he brought to the consideration of the problem an enthusiastic interest and a mental energy rarely found in one no longer young. As I realized increasingly in later years, enthusiasm, earnestness and a keen interest in the matter at hand at all times characterized both the Doctor's work and his play. I was impressed especially by the nervous energy with which he set forth various tentative plans which had been suggested and his eager interest in the possibilities of electricity as developed up to that time in the field of power distribution.

In the late autumn of 1892, I again came in contact with Doctor Sellers when, in response to an invitation from Mr. George Westinghouse, he and Professor Rowland visited Pittsburgh to investigate the possibilities of alternating current apparatus, as then developed, and particularly to test the then new rotary converter and to determine the effect of comparatively low frequencies upon incandescent lamps. From that time until 1897, as engineer of the manufacturing company which constructed and installed the first generators and their electrical equipment at

Niagara, and subsequently for three years as Electrical Director of the Niagara Falls Power Company, during the period when the first 50,000-horse-power plant was completed and put into commercial operation, it was my great, good fortune to see much of the Doctor and of his work. No experience perhaps could give one a more comprehensive, or accurate, knowledge of his character and ability than could be acquired during a period of such close professional relationship, first, from the standpoint of representative of the contracting company, and, later, from the standpoint of mutual interest and coöperation in the work of the Power Company. During those ten years and, indeed, at all times, Doctor Sellers' attitude was that of the ideal engineer—patient, eminently constructive, zealous and tireless in protecting the interests of his client, but always coöperative and never unjust. Seeking to construct no monument to himself, his sole object was to assist in the creation of a successful enterprise and the solution of a fundamental engineering problem of far-reaching importance.

To understand and appreciate the importance of Doctor Sellers' work at Niagara, it is necessary to realize the state of the art of power transmission and distribution at the dates when the decisions of the Cataract Construction Company were made. The most definite plan which had been suggested before Mr. Adams and his associates acquired their charter contemplated an exclusively hydraulic development, a canal of considerable length being used to convey water to mills and factories located at various points convenient to the canal and a parallel outlet tunnel approximately 150 feet beneath the surface discharging into the Niagara gorge below the falls. The power for each mill and factory, or closely adjacent group of mills and factories, was to be developed by its own hydraulic turbines, receiving water from the canal and discharging it into the tunnel. As an alternative to this plan, which was in line with American practice at Holyoke, Manchester and elsewhere, the possibility of one or more large centrally located plants, with some method of transmitting and distributing power, was considered. In presenting its problem, the company indicated no prejudice or preference. The question asked was simply: "How can the power at Niagara best be utilized?"

Under such conditions, the work of the Niagara Falls Power Company demanded from its technical advisers, skill, vision and

judgment of a high order. Fortunately, the management of the company was eminently wise and far-sighted and under its direction the minds of a selected group of the ablest scientists in America and Europe were brought to bear upon the problem of utilizing the power of the great falls. From Europe came Lord Kelvin, Mascart, Turretini, Unwin and Forbes. From America, came Sellers, Herschel and Rowland.

In 1890 the Niagara Commission, comprising Lord Kelvin (then Sir William Thomson), Doctor Sellers, Mascart, Turretini and Unwin, was organized. Of this Commission, Lord Kelvin was Chairman and Unwin, Secretary. Numerous firms and individual engineers were invited to submit plans for the utilization of Niagara power and prizes were awarded by the company. Twenty-two projects were submitted in this competition, twenty from Europe and only two from America, the American electrical manufacturing companies having declined to compete. In the light of present knowledge, it is interesting to note that both of the plans submitted by American companies contemplated the use of compressed air in distributing power, as did also some of the plans submitted by European competitors.

Naturally, the plans suggested and, in many cases, strongly advocated, were various and often divergent. The problem of constructive development faced was complex and difficult. Its solution called not only for analytical and constructive ability of a high order, but for untiring patience, imagination, foresight, and, above all, for sound judgment.

From 1890 to 1893 the engineers selected by Mr. Adams and his associates were engaged in their far-reaching investigation. During this time Doctor Sellers, by his character, his zeal and his sound judgment, established himself gradually in the confidence of the Board until, by making him President and Chief Engineer of the Niagara Falls Power Company, and requiring his approval of all construction plans, they placed upon him final responsibility for all engineering decisions involved in their enterprise. As a designer and inventor, he contributed to the equipment of the first and second power houses at Niagara a number of features of value, including hydraulic governor improvements, thrust bearings, machinery for raising and lowering gates and mechanical features of dynamo design.

Prior to 1890 the practicability of transmitting large amounts

of power by electricity had not been demonstrated. In America, the determining steps in the development of the art of electric transmission were taken between 1885, when the idea of supplying incandescent lamps by alternating current through the intervention of transformers was brought to America, and 1895, when the first alternator was put into commercial service at Niagara. Since then progress in this field has been measured by a gradual increase in size and efficiency of hydraulic and electric units and by step-by-step progress in the development of high-tension insulators and the mechanical supports for transmission circuits. The first plant of the Niagara Falls Power Company involved steps relatively greater than any since taken. In those early days applicable theory was in its infancy, while practical precedent on a comparable scale did not exist.

The extent to which the judgment and painstaking investigation of Doctor Sellers influenced electrical development in America along lines now well established has not generally been recognized. As a member of the International Commission, he opposed successfully a resolution moved by Lord Kelvin himself, which aimed to exclude from further consideration all systems of electrical power transmission other than the direct current systems. Doctor Sellers wisely took the ground that the Commission's knowledge of the possibilities of alternating current at that time was not sufficient to justify action which would close the doors to that system. Fortunately, his opinion prevailed. Few at this time would question the soundness of his judgment.

When the rapid development of alternating current lightning and power systems led to general recognition of the transformer as the key to the problem of electrical transmission, advisers both within and without the Power Company's organization presented for consideration the claim of various voltages and frequencies. The two-phase and the three-phase systems had their respective advocates and strong supporters of various direct current systems still were active. The electrical experts of the Cataract Construction Company failed to agree in regard to various essential features and in exercising his power of supervision and approval of all plans, Doctor Sellers accepted heavy responsibility not only in his own special field of mechanical engineering, but in the hydraulic and electrical fields as well.

From 1889 to 1893 many important questions of engineering

practice, in respect to which there is now practical unanimity of opinion, were earnestly debated. In those years the Doctor, sound in his judgment, concillatory toward others, untiring in his effort to secure what would stand the test of time, was the adviser whose counsel chiefly guided his company in regard to all technical questions. His broad knowledge of physical science and his long experience in dealing with mechanical problems qualified him pre-eminently in an enterprise involving large investment in a new field. From personal knowledge, I can testify that his ability to study a problem objectively and without prejudice, his enthusiastic energy and his courage in assuming great responsibility, were in every way admirable. I can testify also that his high character, his personal charm and his modesty contributed in no small degree to the successful solution of the Niagara problem.

The far-reaching influence of the first plant of the Niagara Falls Power Company upon the development of the art of transmitting power by electricity has been widely recognized and instances might be multiplied in which his foresight avoided, or skill surmounted, difficulties which but for him would have handicapped seriously the remarkable engineering and industrial development to which that plant contributed so much of value.

As an engineer he earned the highest respect of his associates, and of all with whom he had dealings. As a man he won not only the respect, but also the affection of all who were admitted within the circle of his friendship.

In the annals of man's gradual conquest of nature, there is revealed at rare intervals a great discoverer standing like Cortez—"silent upon a peak in Darien"—gazing out upon a newly discovered ocean of truth, but after Cortez the Pacific needed many explorers to follow up his work of discovery and it needed also a Maury to chart its prevailing winds and currents. In like manner every discoverer of a law of nature not only reveals a new field for the scientific explorer, but calls for the engineer to follow the scientist and utilize his vision for the good of mankind. Franklin, whose name this Institute bears, was a philosopher, a statesman, a diplomat, a scientist and he also was, perhaps preëminently, a practical engineer. Among the able men since his day who have been identified with The Franklin Institute, few, if any, have done more than did Dr. Coleman Sellers to make available for human use those dynamic forces of nature so long overlooked.

The President then called upon Doctor McClenahan, Secretary of the Institute, who stated that we had hoped to have with us Doctor Adams, President of the Cataract Construction Company, an intimate associate of Doctor Sellers; that because of his age and the state of his health, Mr. Adams was not able to come from New York, but that he had sent the beautiful floral tribute displayed near the portrait, as his contribution to the memory of a friend whom he still holds dear.

Doctor Eglin then adjourned the meeting with an expression of thanks to Mr. Sellers, and to Doctor Stillwell, for the permanent tribute which he had given us of the standing of Doctor Sellers outside of our own community. He stated further that the work of Doctor Sellers at the Institute needed no testimonial, and that those of us who knew Doctor Sellers felt that we had gained greatly from that contact.

In connection with the presentation of the portrait, Mrs. Colton received a letter from Mr. A. E. Outerbridge, Jr., describing an incident in Doctor Sellers' connection with the Institute. A portion of this very human document is given herewith:

" . . . I was over in the office of the Secretary of the Institute (Prof. Henry Morton) when an inventor was showing to a group of half a dozen engineers a so-called ' unpickable lock,' the peculiar feature being that there was no visible keyhole. The lock was fastened to the underneath side of a highly polished steel plate about seven by eight inches; the upper surface was engraved with fine lines resembling the pattern of watered silk. After careful scrutiny the men all said they could detect no means of finding a keyhole. The inventor then produced a small horseshoe magnet which he said was the only possible ' open sesame.' Placing the magnet on the plate, near the middle, he drew up a piece of the steel plate the size of a keyhole, that had been so skilfully ' mitred ' in, following the engraved lines, that it escaped all observation. The inventor said that unless a burglar had a similar magnet he could not withdraw the mitred piece. This was considered quite ingenious.

" Just then Dr. Coleman Sellers happened in, after the mitred piece had been restored to its place. Doctor Sellers took a small magnifying glass out of his pocket, examined the plate, and said to me, ' Outerbridge, will you please go downstairs to the laboratory, where you will see a long piece of light steel spring from an

old clock. Cut off a piece about four inches long and bring it to me with a piece of beeswax you will find in the drawer of the work bench.' I quickly did this. Doctor Sellers bent the spring into a bow, fastened a little piece of beeswax in the middle, pressed it down on the spot where the inventor had previously placed his magnet, and up popped the mitred piece of steel, causing quite a sensation. The inventor was evidently chagrined, for he picked up his lock and walked out.

"Doctor Sellers explained that by the aid of the magnifying glass he detected at once the mitred piece of steel, and took a chance that the beeswax would stick and the spring would be strong enough to raise the piece from its seat. . . ."

Dogwood and Persimmon Trees Provide Wood for Many Uses. (U. S. Department of Agriculture, Bulletin No. 1436-D.)—That the woods of dogwood and persimmon trees, so necessary for shuttles in the textile industry of the world, are valuable and are becoming increasingly more difficult to obtain, is brought out in a recent publication of the Forest Service, entitled "Utilization of Dogwood and Persimmon." As yet no satisfactory substitutes, either native or foreign, for these two woods have been found.

Many owners of dogwood timber, because of its small size, have not realized its value, and have either not made efforts to market it or have allowed the dogwood and persimmon to be injured when the larger timber associated with it was removed. The new publication stresses the value to the farmer and woodland owner of these woods and urges their most careful utilization.

The publication points to the waste of dogwood and persimmon and the remedy for waste not only in the forest, but at the mill and shuttle factory. It shows that most of the losses occur in seasoning, and it contains suggestions for improved methods of seasoning. It urges that further research be done in impregnating these two woods to make them moisture-resistant, and gives information about other native woods which may possibly serve as substitutes for the dwindling dogwood and persimmon. The supply of these suggested substitutes is mentioned, and the mechanical and physical properties are compared to dogwood and persimmon.

The publication closes with the statement: "Textile and shuttle manufacturers at present display undue confidence in the sufficiency of the supply of raw material for shuttles. Although it is true that curtailment may not be imminent, some organized action and research on the part of those especially interested, will not only go far toward postponing future curtailment of the woods at present used, but may also make available certain native or foreign species not now used, and thus increase the supply of woods suitable for shuttles."

WALTON CLARK MEDAL AND THE PRESENTATION TO DR. WALTON CLARK AS ITS FIRST RECIPIENT.

TUESDAY AFTERNOON, DECEMBER 21, 1926.

THE United Gas Improvement Company of Philadelphia has generously donated to The Franklin Institute sufficient funds for the establishment of a medal to be known as "The Walton Clark Medal," to be awarded for "original and notable work in the gas industry." This medal is given in honor of Dr. Walton Clark,

Obverse. (Reduced.) Reverse.

for thirty-five years an officer of the United Gas Improvement Company, and for seventeen years President of The Franklin Institute.

Because of Doctor Clark's distinguished and valuable contributions to the gas industry, the Board of Managers of The Franklin Institute, upon the hearty and unanimous recommendation of the Committee on Science and the Arts, has awarded the first Walton Clark Medal to Dr. Walton Clark.

Formal presentation of the medal to Doctor Clark was made at special exercises held in the Hall of the Institute at three o'clock on the afternoon of Tuesday, December twenty-first. The exercises were as follows:

The meeting was called to order by the President of the Institute, Doctor Eglin, who announced:

> "This is a special meeting of the Institute, called for the purpose of awarding the first Walton Clark Gold Medal.
>
> "Through the generosity of the United Gas Improvement Company, the Institute has received securities, interest

from which will provide a sum sufficient for the awarding of one medal each year; the balance of such income to be used for the purchase of such books as relate to the gas industry—to be known as 'The Walton Clark Memorial Library.' The deed of the gift, outlining the conditions of the award, has been prepared in the broadest terms by the United Gas Improvement Company officials, so that the medal may be awarded for any invention or appliance or process covering the full scope of the gas industry. The Board of Managers of the Institute desires to extend its thanks for this generous gift.

"The Committee on Science and the Arts has considered the award of the first medal, and has presented its report, which has been unanimously approved by the Board of Managers. I have the honor now of calling upon the Secretary, Doctor McClenahan, to present this report."

The Secretary read the following:

"The Committee on Science and the Arts of The Franklin Institute recommends the award of the Walton Clark Medal to Dr. Walton Clark, of Philadelphia, 'in consideration of his life work in the American gas industry and his distinguished and outstanding contributions to technical progress in that industry, as a pioneer in the association of chemical and physical laboratories with the developmental work of the gas companies, by his participation through interest, suggestion and advice in the invention of a process for the complete gasification of coal, in the development of processes for operating water-gas sets, and in the institution of beneficial modifications of water-gas apparatus, by numerous articles contributed to the technical press, and by his unfailing interest in the educational progress and the all-around development of the younger men who were fortunate enough to be associated with him.'"

The Secretary then presented Doctor Clark for the award, which was made by the President in the following terms:

"Dr. Walton Clark: By virtue of the authority conferred upon me as President of The Franklin Institute, and upon the recommendation of the Institute's Committee on Science and the Arts, I have the honor to present to you the

first Walton Clark Gold Medal. On behalf of the Board of Managers, I desire to record their satisfaction and pleasure that this medal has been awarded to you. In the many years most of the present members of the Board of Managers have approved the recommendations of medals, they feel there has been no instance, because of their personal knowledge and contact with you, in which the award has been more highly deserved than in this case, which has their hearty and enthusiastic approval."

In accepting the medal, Doctor Clark responded:

"Mr. President: I thank you for the kindly words with which you have presented the Walton Clark Medal to me. I thank The Franklin Institute for this honor which they have given me, and which I fear is all too little deserved. I thank my friends and associates for taking an hour of a busy day to see me receive this honor. I am feeling very grateful, and also not a little humble."

The Secretary then read several congratulatory messages which had been received from members of the Board of Managers who were unable to be present, and from other friends of Doctor Clark.

The President adjourned the meeting, after which an informal reception was held by Doctor Clark.

The Angles of Incidence for Which the Intensity of Regularly Reflected Radiation Is a Minimum. K. PFANNENBERG. (*Zeit. f. Phys.*, **37**, Nos. 10 and 11.)—It is commonly stated in the case of a ray of light falling upon a reflecting surface of a transparent substance that the intensity of the reflected ray increases as the angle of incidence becomes larger. This is easily confirmed by observing the back of one's hand under different angles. This relation has, however, a limitation that is not generally known. It holds only for such substances as have for the radiation concerned an index of refraction not greater than 3.732. When the index exceeds this limit, there is a certain angle of incidence for which the intensity of the reflected radiation is a minimum. Jentzsch-Graefe has called attention to the limitation and some reference is found in Mascart's "Traité d'Optique." For cases of reflection where the index of refraction does not exceed 3.732 the angle for minimum reflection is

0°. An increase beyond the limiting value causes the shifting of the angle of minimum reflection to ever greater departures from perpendicular incidence. The usual methods of demonstrating this displacement of the angle fail because for visible radiation no substance has an index of refraction larger than 3.732. Recourse must consequently be had to electrical waves for which the index of water is 8.9. The author therefore set up an apparatus in the University of Marburg by which a train of electrical waves of 25 cm. length fell upon a free surface of water in a wooden vessel, 120 by 125 by 20 cm. in dimensions. The receiving apparatus consisted of a linear crystal detector joined to a galvanometer.

The source of waves could be made to emit radiation with its electrical vector either perpendicular to or parallel to the plane of incidence with the water surface. From the galvanometer deflection the percentage of radiation reflected was calculated for both directions of the vector and the percentage for unpolarized radiation was found by taking the average of the two. In the case of the vector being perpendicular to the plane the percentage of incident radiation reflected from the water surface increases from 64.2 when the angle of incidence is 0° to 100 for 90°. With radiation having the vector parallel to the plane, the percentage reflected at 0° is again 64.2. As the angle grows larger it grows smaller until at 83° only .47 per cent. of the incident radiation is reflected. For larger angles the percentage increases, reaching a value of 98 for 90°. The curve showing the change of the percentage of reflected unpolarized radiation closely resembles in general form that for radiation with the vector parallel to the plane. For unpolarized radiation the angle of minimum reflection is 83° where 47.7 per cent. of the incident light is reflected.

According to theory this angle should be smaller provided the index of refraction of the reflecting material be less than that of water. There are no strictly solid substances with indices larger than 3.732. According to Debye's Dipole Theory it is only in liquids that so high indices may be found. The cost of many otherwise available substances precluded their use, so that solutions of sodium chloride were finally used. For a 3 per cent. solution the angle of incidence for minimum reflection was 82° with 47.3 per cent. reflected. The corresponding quantities for 10 and 30 per cent. solutions are 82°, 46.8 per cent. and 80°, 44.1 per cent. The indices for the last two solutions were 7.8 and 7.65, respectively. Determination of the minimum angle was made also on a mass of impure asphalt. No minimum angle was found for unpolarized radiation. Indeed none should have been expected as the value of the index of refraction was 1.7. The reliability of the method of measurement used was further confirmed by applying it to radiation reflected from a metal. Here there was no change in the percentage of light reflected when the angle of incidence varied. This was what was expected. G. F. S.

NOTES FROM THE NELA RESEARCH LABORATORY.*

ELECTRICAL AND THERMAL CONDUCTIVITY AND PERIODIC SYSTEM OF ELEMENTS.

By Richard Rudy.

ATTEMPTS to correlate the electrical and thermal conductivity with the place in the periodic system of the elements have been only partly successful; although in general the conductivity of the elements decreases from a maximum for the first element of the period (or half-period), where only one valence electron is evidently present, new high marks are reached within the periods for Cr, Mo, and W. The analysis of the spectral terms of Cr and Mo is at present fairly complete and shows that contrary to what might be expected, these elements possess *one single electron* in their outermost orbit. This is due to the rivalry between the n_3 or "d" and the $(n+1)_1$ or "s" orbits; these elements are unable to retain both $(n+1)_1$ electrons in their outer group.

	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu
Electrons in 3_3 orbits	0	0	1	2	3	5	5	6	7	8	10
Electrons in 4_1 orbits	1	2	2	2	2	1	2	2	2	2	1
Normal state	^2S	^1S	^2D	^3F	^4F	^7S	$^6S_3$	^5D	^4F	^3F	^2S

and similarly

	Rb	Sr	Y	Zr	Cb	Mo	Ru	Rh	Pd	Ag
Electrons in 4_3 orbits	0	0	1	2	3	5	6	7	10	10
Electrons in 5_1 orbits	1	2	2	2	2	1	2	2	0	1
Normal state	^2S	^1S	^2D	^3F	^4F	^7S	^5F	^4F	^1S	^2S

The spectra of the last long period, including the W spectrum, have not yet been sufficiently analyzed; but there is little doubt that the term ^7S predominates as regards intensity and absorption; the ultimate lines excited, for instance, by active nitrogen are also due to the ^7S state.

Consequently the presence of a single n_1 electron in the normal state S of the atom seems decisive for high thermal or electric conductivity, so much that the unexpected structure for the elements Cr, Mo, W could have been predicted before even their spectrum had been analyzed. The drop in conductivity from Rh to Pd is also accompanied by the loss of 5_1 electrons.

The arrangement of the terms in the spectrum is of course due

* Communicated by the Director.

to the distribution of the electrons in the atom, and if the properties of the atom are preserved, qualitatively at least, in the metallic state, the orbits cannot have been destroyed in passing to the metallic state except that the binding of the electrons is probably weakened. The assumption that the conductivity is due to the outermost electron of the atoms gains thus strong support from the results of spectroscopy. As the orbit n_1 is a very long "ellipse," divided into an inner and outer loop, the electrons may also penetrate into the neighboring orbits, particularly if the atoms are closely packed. The work to split off an electron must of course also be considered; it is relatively lower for one single electron than for one of a pair of electrons and increases from the left-hand side of the period towards the right-hand side.

The study of the spectrum of elements having several outer electrons has revealed the fact that most of the atoms can exist in metastable modifications. Thus, an elevation in temperature of several hundred degrees transforms part of the Tl atoms with 6_1 orbits into atoms with 6_2 orbits. It is to be expected that these transformations are still possible to some extent for atoms in the solid state, where they may cause certain allotropic modifications.

THE FIXATIONAL PAUSE OF THE EYES.[1]

By P. W. Cobb and F. K. Moss.

[ABSTRACT.]

WHILE work has been done by others on this problem, it was felt to be of importance to make some check upon the results as the point becomes of especial interest in connection with earlier work on "Speed of Vision."[2]

If the eyes are focussed at a definite point and a test-object is exposed at this point, the object can be recognized within a time ranging from a few thousandths of a second to about 0.3 second, depending upon several factors, such as the brightness and size of the object. However, in ordinary work the eyes are not fixated upon a definite point, but are continually in motion. Their movement has been shown to consist mainly of rapid sweeps with brief pauses. During such sweeps it is obviously impossible to recognize detail since the image is rushing across the retina at a corre-

[1] *Jour. Exper. Psychol.*, 9, 1926, 259–367.

[2] *Trans. I. E. S.*, 19, 1924, 150–167.

sponding rate. The pauses are frequent, as many as two to seven in reading a single line of print. It is only during these instants of time when the image is nearly or quite at rest that an adequate impression can be made.

The results from a total of 1900 measurements, made with nine subjects, indicated that the average fixational pause of the eyes, between 10° sweeps, is close to 0.15 second. The separate measurements fell nearly symmetrically on either side of this mean, and few pauses were found as short as 0.07 second and very few as long as 0.25 second.

VARIATIONS OF PUPILLARY APERTURE.[1]

By L. L. Holladay.

THE diameter of the pupil of the eye under various lighting conditions has recently been studied by the use of a double-pinhole pupillometer. It was found that when the eye was adapted to perfect darkness for some time the diameter of the pupil was a maximum, K. For three observers the value of K was 6 to 8 mm. When, however, the eye was adapted to a uniform field brightness of F millilamberts, the pupillary diameter P was given by the empirical equation

$$P = K\varepsilon^{-0.16\,(F)^{0.4}},$$

where ε is the base of the natural or Naperian system of logarithms.

If, when the eye is adapted to a given field brightness, the field brightness be suddenly increased, the pupil suddenly contracts. The percentage of contraction is a complex function of the logarithm of the percentage increase in field brightness.

It was found that a light-source in the field of view, but at an angle to the line of vision, influenced the size of the pupil in about the same manner as would a definite field brightness. The greater the illumination at the eye from the light-source, or the less the angle between the light-source and the line of vision, the greater the equivalent field brightness.

It was further found that the size of the pupil varied with the distance from the eye to the object observed; but that the variation was due not so much to focal adjustments as to the convergence of the eyes.

[1] *Jour. Op. Soc. Am.* and *Rev. Sci. In.*, **12**, No. 4, p. 271, April, 1926.

The Question of the Magnetic Rotation of the Plane of Polarization of Primary X-rays. W. KARTSCHAGIN and E. TSCHETETWERIKOWA, Moscow. (*Zeit. f. Phys.*, **39**, No. 12, 1926.)—After Hertz had demonstrated the existence of the waves predicted by Maxwell many experiments were performed to show that electromagnetic waves have the same properties as waves of light. Indeed it would be rash to state that all parallelisms have already been investigated and established. In the early days of X-rays similar eagerness was manifested in comparing them with light waves but the results were for a long time discouraging. In recent years, since it has been proved that X-rays are made up of waves of very short length, the comparison of these two kinds of radiation has been resumed with much success until now it is possible to find in this Journal such a paper as that of Mr. MacMahon on "The Dispersion of X-rays."

The authors of the present paper investigate the effect of a magnetic field upon the plane of polarization of X-rays that pass through paraffin and iron. These substances were selected because, when the tube was operated with 26,500 to 30,000 volts, the characteristic radiation of one of them has a frequency close to that of the wave-length of maximum energy in the primary radiation, while in the other the two are widely separated. Thus by the employment of these two substances the question of the rotation of the plane in the vicinity and of an absorption band, on the other hand, remote from it was examined. Besides this the interesting case of a ferromagnetic substance was included.

With paraffin no rotation of the plane of polarization too large to be attributed to errors of observation was found. A study of the effect from the point of view of the electron theory led to the conclusion that no observable effect was to be expected. In the case of X-rays traversing iron no rotation of the plane was established by experiment. Theory indicated that an effect should have been found but that its exact measurement would be difficult. G. F. S.

Imports of Petroleum. (*Amer. Petroleum Inst. Bulletin*, Feb. 23, 1927.)—Imports of petroleum (crude and refined oils) at the principal United States ports for the week ended February 19th totaled 1,141,000 barrels, a daily average of 163,000 barrels, compared with 1,813,000 barrels, a daily average of 259,000 barrels for the week ended February 12th and a daily average of 195,536 barrels for the four weeks ended February 19th.

Kilauea Growing Uneasy. (*Science News-Letter*, Feb. 19, 1927, p. 119.)—Kilauea volcano, the largest of known active peaks, is showing signs of uneasiness, according to Director T. A. Jaggar of the Hawaiian Volcano Observatory. The seismographs at Volcano House are recording frequent earthquakes, there has been a marked increase of avalanches into Halemaumau Pit, and there are yellow sulphurous patches on the slopes which are increasing in area.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

A CHEMICAL ASPECT OF SULPHIDE SENSITIZING.[1]

By K. C. D. Hickman.

THE suggestion is advanced that the sulphide sensitivity speck of the high-speed silver bromide emulsion grain plays a chemical part during light exposure by serving as a rival halogen absorber. The reaction is of secondary order and does not involve optical sensitizing. An experiment is described in which silver sulphide deposited in an unexposed photographic film is oxidized by silver bromide under the action of light and an increased yield of metallic silver produced. Because this reaction is quite different from that between bromine and silver sulphide under ordinary laboratory conditions, it is considered probable that the reaction will take place even more certainly during latent image formation. Assuming the absence of aerial oxidation, the full course of latent image formation could be written thus:

Equation I.—

$$2AgBr \xrightarrow{+E} 2Ag + 2Br \xrightarrow{+Ag_2S} 4Ag + S_2Br_2 \xrightarrow{+H_2O} HBr$$

$$+ (S_2, O) \begin{cases} \xrightarrow{} 2SO_3 \xrightarrow{} 2H_2SO_4 \\ \xrightarrow[+5H_2O]{} 10H \xrightarrow{} 10Ag + 10HBr; \end{cases}$$

$$\text{total Ag} = 16Ag_{\text{metal}}.$$

Equation II.—

$$2AgBr \xrightarrow{+E} 2Ag + 2Br \xrightarrow{+Ag_2S} 2AgBr$$

$$+ S \begin{cases} \xrightarrow[3H_2O]{+H_2O} SO_3 \xrightarrow{} H_2SO_4 \\ \xrightarrow[3H_2O]{} 6H \xrightarrow[+6AgBr]{} + 6Ag + 6HBr; \end{cases}$$

$$\text{total Ag} = 8Ag_{\text{metal}}.$$

* Communicated by the Director.

[1] Communication No. 286 from the Research Laboratories of the Eastman Kodak Company and published in *Phot J.*, 67, 34 (1927).

It is not claimed that these particular chain reactions are the ones involved. Aerial oxidation might remove some of the reducing power; the action might stop short at sulphite; gelatin might play a part. Other speculations are made concerning certain consequences of the theory.

Wood Alcohol Called Methanol. (*Ind. and Eng. Chem.*, Feb., 1927, p. 227.)—The term "methanol" has been officially adopted by the United States Public Health Service as representing "wood alcohol," and will be used in future in lieu of the latter term in all correspondence and regulations.

Among the advantages which it is believed will result from the substitution of "methanol" for "wood alcohol" is that it will tend to protect the "class of people to whom the word 'alcohol' may suggest a substance suitable for use as a beverage." It is hoped by Public Health Service officials that by use of the term "methanol" the number of casualties caused by the improper use of wood alcohol will be reduced.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

A NOTE ON THE KEEPING QUALITY OF CRUDE PEANUT OIL.[1]

By Walter F. Baughman and George S. Jamieson.

[ABSTRACT.]

A FEW preliminary experiments conducted in the Bureau of Chemistry indicated that if all of the foots are removed from crude peanut oil the keeping quality is very good indeed. If the crude oil remains in contact with the foots the oil deteriorates much more rapidly in most instances.

THE ISOELECTRIC POINT DETERMINATION IN CORN SUGAR AND CORN SYRUP MANUFACTURE.[2]

By H. S. Paine and M. S. Badollet.

[ABSTRACT.]

IN THE manufacture of corn syrup and corn sugar there has been some uncertainty as to the best manner of controlling the neutralization of converter liquor with sodium carbonate in order to obtain the maximum flocculation and elimination of the colloidal material present. Experiments conducted in the Bureau of Chemistry have indicated that it is feasible to control the addition of sodium carbonate to converter liquor by isoelectric point determinations, thus obtaining consistent maximum colloid elimination at this stage of the factory process in the manufacture of corn syrup and corn sugar.

A NEW PAINT AND VARNISH REMOVER.[3]

By Max Phillips and Marshall J. Goss.

[ABSTRACT.]

EXPERIMENTS having shown that mixtures of p-cymene with certain organic solvents are excellent paint and varnish removers, several such solutions were tested in the Bureau of Chemistry.

* Communicated by the Chief of the Bureau.

[1] Published in *J. Oil and Fat Industries*, **3**, Dec., 1926, pp. 431, 449

[2] Published in *Facts About Sugar*, **21**, Dec. 18, 1926, pp. 1212–1213.

[3] Published in *Chem. and Met. Eng.*, **33**, Dec., 1926, p. 745.

These tests showed that the most effective paint and varnish remover of the solutions tested is the one composed of ethyl alcohol and p-cymene or methyl alcohol and p-cymene in the proportion of 1 to 1 by volume.

New Lamp Reveals Mine Gas. (*Journal A. I. E. E.*, Feb., 1927, p. 148.)—A new type of electric safety lamp was recently displayed in Vienna, in which the filament is made up of a series of semi-circular loops of palladium and the bulb is stopped with a disc or porous stone. The base fits the standard lamp socket.

In a normal atmosphere, the ends of the filament show dark red. When methane gas, the deadly fire damp, is present in the air, the centre of the filament becomes brilliantly incandescent, and when 8 per cent. or more of methane gas is present, the centre of the filament continues to glow after the current is turned off.

Astronomical Clock Controls City's Street Lights. (*Popular Mechanics*, March, 1927, p. 399.)—Street lamps on part of the system in St. Louis, Mo., are turned on at sunset and off at sunrise by an astronomical clock without the aid of human hand. The instrument adjusts itself to seasonal variations, saving current and eliminating the need of an attendant except for an occasional cleaning. At the proper time in the evening and in the morning, contacts on a drum in the clock operate the circuits which carry the lighting load. In case of trouble, protective relays are provided for every kind of emergency. For inspecting and testing, the system also can be operated by hand.

NOTES FROM THE U. S. BUREAU OF MINES.*

COMPOSITION OF MATERIALS FROM VARIOUS ELEVATIONS IN AN IRON BLAST FURNACE.

By S. P. Kinney.

THE Bureau of Mines recently completed an investigation of the gas composition, temperature, and pressure at a series of planes in a blast furnace making foundry iron in the southern district. Samples of coke, metal, slag, limestone, and stock were recovered from points between the tuyere plane and stock line. If complete and representative samples of stock could be obtained from various points across a series of planes between the stock line and tuyere level while the furnace is in operation, analyses of these samples would present a clear picture of most of the steps in the reduction process. Aside from giving the position of the zones of reduction, calcination, and slag formation, the samples are valuable in determining where the iron acquires its carbon, sulphur, phosphorus, manganese, and silicon.

A complete description of the tests and results obtained are given in Technical Paper 397, which recently appeared.

EFFECTS OF THE CORONA DISCHARGE ON PETROLEUM.

By J. J. Jakosky.

EXPERIMENTS were made to determine the effects that high-voltage alternating-current electricity in the form of the corona discharge has on petroleum vapors. Technical Paper 351 discusses previous tests of the effects of electric arcs on petroleum and the production of carbon black. The work is a part of that undertaken by the Bureau of Mines in the effort to increase efficiency in the utilization of petroleum.

The recent experiments are divided into five sections: (1) Hydrogenation using commercial compressed hydrogen gas and natural gas; (2) polymerization of benzene by the corona; (3) cracking petroleum by using a high-voltage corona discharge; (4) precipitation of hot-oil vapors; and (5) cracking by the

* Communicated by the Director.

corona without external heating. Because conditions prevailing in these experiments differ, the apparatus, procedure, and results obtained differ for each section.

Some of the principal results of these investigations may be summarized thus: Electrical activation of hydrogen is of such small magnitude as to be negligible in the refining of petroleum and production of gasoline. Benzene was polymerized by use of the corona discharge. Suggestions are made and attention is called to the importance of further work in this direction. The use of a corona discharge in a vapor-phase cracking furnace is shown to give an increased yield. The work showed that a critical temperature existed below which an oil vapor existed as a mist, was visible in a strong beam of light, and could be precipitated by a corona discharge. The corona discharge in itself produced no cracking of the gas oil present in the vapor phase.

Further details on the tests will be found in Technical Paper 375, recently published by the Bureau of Mines.

MANUAL OF TESTING METHODS FOR OIL SHALE AND SHALE OIL.

By Lewis C. Karrick.

ALTHOUGH the Bureau of Mines has thus far made no large-scale experiments with oil shales, and the feasibility of the commercial manufacture of shale-oil products suited to present market requirements has not been demonstrated, there is ample reason to believe that these products will eventually supplement the more commonly used petroleum products and give equally good service. In 1919 the Bureau, in coöperation with the Department of Metallurgical Research, University of Utah, began investigating the oil shales of the United States to obtain detailed information on their value. The States of Colorado and Indiana also coöperated through their state universities, in which research laboratories were organized to assist in carrying on the oil-shale studies planned and directed by the Bureau. As a result of these studies much information is now available concerning laboratory methods of producing the greatest yields of the best products from oil shale.

In order to study the principles that govern the retorting of oil shales and to test the oils produced, it has been necessary to

develop and standardize reliable apparatus and methods for distilling shale, and to adapt to the testing of shale oils some of the methods the Bureau of Mines uses for testing petroleum. The methods employed by the Scottish shale-oil manufacturers were also studied, but most of them have been superseded by methods which give more comprehensive and accurate results and employ more convenient apparatus. Bulletin 249, just published, is a manual of apparatus and methods that the Bureau had developed for work on oil shale and found satisfactory for routine tests and for research. Explanation and discussion of the principles underlying the methods of testing are included wherever necessary for a clearer understanding.

OIL-FIELD EMULSIONS.

By D. B. Dow.

OIL-FIELD water trouble is probably the most perplexing technical problem the producer must solve. The presence of water directly affects the quantity of oil recovered and the life of a field. Water also increases the cost of operating, as it augments lifting costs and also corrodes equipment, necessitating frequent replacement, to prevent permanent injury or complete destruction of wells. Furthermore, water may lower the market value of the oil produced by helping to form detrimental water-in-oil emulsions, such as B. S. and cut oil.

The results of a recent investigation by the writer are presented in Bulletin 250, of the Bureau of Mines. This bulletin deals entirely with the cause and removal of water emulsified in crude petroleum and the colloidal theories involved. The results of investigations of other phases of the water problem by the Bureau of Mines have been published.

IN ITS weekly "Calendar of Discovery and Invention" *Nature*, Jan. 29, 1927, says, "February 5, 1870.—At the Academy of Music, Philadelphia, on February 5, 1870, before an audience of more than 1500 people, Henry Heyl publicly exhibited on the screen a series of posed pictures showing the movements of a couple waltzing. The effect was obtained by placing photographs around the edge of a disc which was driven step by step in strict time with the music of the orchestra. This was the first public motion picture show, and the Academy has been popularly called 'the birthplace of the movie.'" Mr. Heyl was for many years a prominent member of The Franklin

Institute. To his son, Dr. Paul R. Heyl, now engaged in determining the constant of gravitation at the Bureau of Standards, the Institute awarded a part of the Boyden Premium. G. F. S.

Special Weather Reports for Commercial Airways.—In carrying out the provisions of the Air Commerce Act of 1926 the Weather Bureau of the Department of Agriculture since July of this year has inaugurated special service at seventeen places selected by the Department of Commerce, the Post Office Department and the Department of Agriculture as those best located to furnish information concerning weather conditions to fliers along commercial airways. The service includes observations of upper winds by means of small "pilot" balloons, and these observations are as a rule taken a short time before the planes are scheduled to make their flights. The information enables pilots to select the most favorable altitude for flight, or the least unfavorable altitude in case head winds prevail at all levels.

An important feature of the service is the transmission of weather reports from point to point along the airways. The pilot is, if anything, more interested in conditions at places toward which he is about to fly than he is in those at the place from which he starts. Obviously the information, to be of most value, should reach the pilot as short a time before his departure as possible. Thus, if a pilot starts out on a two-hour flight, and a report tells him as he leaves that the weather at his destination is good and that the outlook for the next two or three hours is favorable, he proceeds with a much greater degree of confidence than if he had no such information. Changes during a flight, even of that short duration, may and do occur, and it is planned ultimately to extend the weather reporting service to include special observations, when advisable, which will be sent to emergency landing fields en route, equipped to set up warning signals, upon seeing which the pilot will either land or turn back. For the present, however, the service will be limited to reports at stated hours, shortly before the departures of planes. It will be organized along all commercial airways where flying is on a regular schedule basis. Instructions to put it into effect along two of the airways have recently been issued. These are the Chicago-St. Louis and the Chicago-Dallas Airways. Along the former, special reports are exchanged between Chicago, Peoria, and St. Louis, and along the latter, between Chicago, Moline, Kansas City, Wichita, Oklahoma City and Dallas. The reports give upper wind conditions, height of clouds, visibility, the occurrence of fog, rain, thunderstorm or any other unfavorable or threatening condition. As the service develops, it seems likely that, as in other countries, so in this, the weather reports will be a large factor in determining whether or not a scheduled flight shall be made, and, if made, what height will be selected as the safest and most economical.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting Held Wednesday, February 16, 1927.)

THE meeting was called to order at eight-sixteen P.M. by the President, Wm. C. L. Eglin, who announced that this was the regular monthly meeting of the Institute, and called upon the Secretary for the business of the evening.

The Secretary stated that the minutes of the last meeting had been published in full in the February number of the JOURNAL of the Institute and moved, therefore, that they be approved as printed. There being no objection, the President declared the minutes approved.

The Secretary announced that since our last meeting four Resident and one Student member had been elected to the Institute, and that there had been no losses by death or resignation during that interval.

On behalf of the President the Secretary read the following lists of members of the Committees of the Institute for 1927:

Committee on Library.

W. H. Fulweiler	Joseph S. Hepburn
C. W. Bates	George A. Hoadley
Charles E. Bonine	Lionel F. Levy
H. J. M. Creighton	M. M. Price
Clarence A. Hall	George F. Stradling

Committee on Meetings.

Howard McClenahan, Chairman	Charles Penrose
James Barnes	George D. Rosengarten
George S. Crampton	Coleman Sellers, 3rd
Arthur W. Goodspeed	W. F. G. Swann
George A. Hoadley	William Chattin Wetherill

Committee on Museum.

Hugo Bilgram, Chairman	George A. Hoadley
G. H. Benzon, Jr.	John J. L. Houston
Arthur L. Church	Henry Leffmann
Theobald F. Clark	H. H. Quimby
W. C. Wagner	William O. Sawtelle

The President announced that these gentlemen would constitute the Committees for the present year.

The Secretary stated that the list of meetings for the balance of the Institute year was in the hands of the printer and would be distributed to the members in the very early future. He read the list and called especial attention to the fact that on March thirty-first, Dr. H. A. Lorentz, of the University of Leyden, Holland, one of the leading mathematical physicists of the

world, would address the Institute on the subject, "How Does the Atom Radiate Light?"

The Secretary further made a statement concerning the three prizes which were awarded upon the basis of the books of notes based upon the lectures delivered before the Institute during Christmas Week by Prof. R. W. Wood, of Johns Hopkins University. The first prize of fifty dollars was awarded to Oscar H. Schuck, Jr., the second prize of twenty-five dollars to Frank G. Raysbrook, and the third prize of ten dollars to Glenden J. Dunlap. These three young gentlemen were all students of the Northeast High School of Philadelphia. The first prize was donated by the President of the Institute, and the second and third prizes by Mr. Henry Howson, one of the Vice-presidents.

There being no further business, the President of the Institute introduced as the lecturer of the evening Prof. B. Smith Hopkins, Department of Chemistry, University of Illinois, for many years a student of the rare earths, an investigator of the atomic weights of a number of the rarer elements, and the discoverer of element 61, to which he has assigned the name "illinium."

Professor Hopkins read a delightful and convincing paper, in which he outlined the brilliant work which had led to the identification of element 61, and in which he paid a very considerate tribute to other scientists who had been working in the same field.

The paper of the evening was followed by discussion, participated in by several persons. The meeting adjourned at nine-forty-four, with an expression of hearty appreciation to Professor Hopkins for the fine paper which he had read, and a vote of thanks for the trouble he had given himself to come from Illinois to Philadelphia. Adjourned.

HOWARD MCCLENAHAN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting Held Wednesday, February 2, 1927.)

HALL OF THE COMMITTEE,
PHILADELPHIA, February 2, 1927.

DR. JAMES BARNES *in the Chair.*

The Chairman announced the reëlection by the Board of Managers of nineteen members of the Committee to serve for three years and the election of the following new member to serve for three years:

MR. JAMES D. LEE, JR.

The Special Committee on Nomination of a Chairman for the ensuing year reported as its choice MR. M. M. PRICE. Mr. Price was unanimously elected and took the Chair.

The following reports were presented for final action:

The Franklin Medal, Dr. James Barnes, Chairman.

No. 2863: To Dr. Max Planck, of Berlin, Germany, "in recognition of his valuable contributions to the field of thermodynamics, particularly for his law of radiation, in the development of which he employed, for the first time, the

revolutionary idea of the fundamental indivisible quantity of radiant energy called the 'quantum.'"

No. 2864: To Dr. George Ellery Hale, of Pasadena, Calif., "in recognition of his numerous and highly important researches, inventions and discoveries in solar physics, of his eminent success in organizing and directing astronomical observatories and of his establishment and promotion of plans and means for coördination and advancement among the sciences."

The following reports were presented for first reading:

No. 2847: The Hardinge Air Classifier.

No. 2865: Literature.

GEO. A. HOADLEY,
Secretary to Committee.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 9, 1927.)

RESIDENT.

MR. A. E. BLAKE, Sales Engineer, U.G.I. Contracting Company, Broad and Arch Streets, Philadelphia, Penna. For Mail: 1401 Arch Street, Philadelphia, Penna.

MR. L. KENT KEAY, Textile Manufacturer, Clifton Heights, Penna. For Mail: 48 East Stewart Avenue, Lansdowne, Penna.

MR. GEORGE NOX MCCAIN, Editor, Evening Bulletin. For Mail: 4008 Pine Street, Philadelphia, Penna.

MR. CHARLES A. YOUNG, Teacher, Northeast High School. For Mail: Somerton, Philadelphia, Penna.

STUDENT.

MR. WILLIAM D. BRUCE, Student, 152 Rhoads Avenue, Haddonfield, N. J.

CHANGES OF ADDRESS.

COLONEL G. L. ANDERSON, Army and Navy Club, Washington, D. C.

MR. ALFRED CROOK, 1506 Widener Building, Philadelphia, Penna.

DR. KARL K. DARROW, 230 West 105th Street, New York City, N. Y.

MR. FRANKLIN W. GILMAN, 4700 Wissahickon Avenue, Germantown Station, Philadelphia, Penna.

MR. LIONEL F. LEVY, Wayne Avenue and Berkeley Street, Germantown, Philadelphia, Penna.

MR. HERMAN LIVINGSTON, 1341 Marlborough Avenue, Plainfield, N. J.

MR. CHARLES H. NORDHAUS, Care of Neway Radio Sales, 3943 Lawrence Avenue, Chicago, Ill.

MR. RALPH W. POPE, 16 Castle Hill Avenue, Great Barrington, Mass.

MR. JOHN B. RUMBOUGH, P. O. Box No. 2, Asheville, N. C.

MR. HENRY P. RUST, 225 South Fifteenth Street, Room 1411, Philadelphia, Penna.

MR. A. D. SILVA, 346 Burns Street, Forest Hills, Long Island, N. Y.
DR. ALEXANDER R. STEVENSON, JR., General Electric Company, 1 River Road, Schenectady, N. Y.
MR. CLIFFORD J. SUMMERS, Nicollet, Minn.
MR. J. S. TATNALL, Eleventh Floor, 1835 Arch Street, Philadelphia, Penna.
MR. EDWARD L. ZIESEL, Laboratory of the Big Sisters Hospital, Ventura, Calif.

LIBRARY NOTES.

RECENT ADDITIONS.

Analyst: the Journal of the Society of Public Analysts and Other Analytical Chemists. Decennial Index Volumes 41–50, 1916–1925.
AVRAM, MOÏS H.—The Rayon Industry. 1927.
BLIGH, N. M.—The Evolution and Development of the Quantum Theory. 1926.
BLYTH, HERBERT.—Modern Telepherage and Ropeways. 1926.
BRUNET, PIERRE.—Les Physiciens Hollandais et la Méthode Expérimentale en France au XVIII^e Siècle. 1926.
COHEN, ERNST.—Physico-chemical Metamorphosis and Some Problems in Piezochemistry. 1926.
CRANSTON, J. A.—The Structure of Matter. 1925.
Economic Geology.—General Index Volumes 1–20, 1905–1925. 1926.
FLINN, A. D., WESTON, R. S., and BOGERT, C. L.—Waterworks Handbook of Design, Construction and Operation. Third edition. 1927.
GONSETH, F.—Les Fondements des Mathématiques: De la Géométrie d'Euclide à la Relativité Générale et à l'Intuitionisme. 1926.
HASLAM, ROBERT T., and RUSSELL, ROBERT P.—Fuels and Their Combustion. 1926.
Klimschs Jahrbuch. Band 20. 1927.
KRAMERS, H. A., and HOLST, HELGE.—The Atom and the Bohr Theory of Its Structure. 1923.
MOYER, JAMES AMBROSE.—Power Plant Testing. Third edition. 1926.
Optical Convention.—Catalogue of Optical and General Scientific Instruments. 1926.
Optical Convention.—Proceedings 1926, Parts 1–2. Two volumes. 1926.
OSTWALD, WOLFGANG, and Others.—Practical Colloid Chemistry. Translated by I. N. Kugelmass and T. K. Cleveland. No date.
Photograms of the Year 1926.
WAESER, BRUNO.—The Atmospheric Nitrogen Industry. Translated by Ernest Fyleman. 1926.
WIEN, W., and HARMS, F., Editors.—Handbuch der Experimentalphysik. Volume I: Ludwig Holborn, Messmethoden; Ernst von Angerer, Technik des Experiments. Volume 14: P. Lenard und A. Becker, Kathodenstrahlen; Wilhelm Wien, Kanalstrahlen. Two volumes. 1926–1927.
WILE, FREDERIC WILLIAM.—Emile Berliner: Maker of the Microphone. 1926.
WOODS, A. T., and STAHL, A. W.—Elementary Mechanism. Revised and rewritten by Philip K. Slaymaker.
World Almanac and Book of Facts for 1927.

BOOK REVIEWS.

CATALYSIS IN THEORY AND PRACTICE. By Eric K. Rideal, Cambridge University, and Hugh S. Taylor, Princeton University. Second edition, xv–516 pages, 8vo, illustrated. London, Macmillan and Company, Ltd., 1926.

The word "catalysis" was coined in 1836 by Berzelius, but four years previously Döbereiner had published one of the most interesting and puzzling examples of the action in showing that manganese dioxide would materially aid the decomposition of potassium chlorate without being itself appreciably affected. The present reviewer, in his salad days, being curious to test the statement that the dioxide can be used many times, tried out the matter by extracting the residual soluble salts and using the catalyst again. This was done six times with no appreciable loss of activity and the youthful scepticism was satisfied. It appears from the preface that in 1812, Edmund Davy suggested the use of platinum sponge as a catalyst in the oxidation of sulphur dioxide, a procedure which has since developed into a great industry.

The progress in the study of catalytic action and the extension of the use of catalysts in recent years has necessitated a re-writing of the book, which is now brought up to date by a thorough revision of the text and the addition of several chapters. Progress in theoretical views will go more or less with progress in the practical, though the former not infrequently precedes the latter and determines its course. We are told in the preface that the concept first postulated by Arrhenius of "active" molecules is beginning to be indicated. In contact catalysis, research has yielded a definite concept of the solid catalytic agent, thus passing beyond the mere surmises of a few years ago.

In industrial fields many uses have been made of catalysts among which may be mentioned the manufacture of sulphuric acid, the fixation of nitrogen and the recently established manufacture of methanol from water gas. One of the features of recent years has been the use of very high pressures and temperatures, thus departing from the earlier methods which were usually biologic and, therefore, carried on at or about the normal temperature of living organisms. The fixation of nitrogen by the Haber process had a profound influence upon the course of the world's history, for it seems established that if Germany had not been able to supply its ammonia and nitrates in abundance within its own bounds, it could not have maintained the war for more than a few months. In a German work on nitrogen fixation published shortly after the armistice, it was stated that from the time the British blockade was established shortly after the declaration of war, until the middle of January, 1915, only about 5000 tons of Chile nitrate entered the ports of Germany. The Haber process then in full development furnished ample supplies of fertilizers and nitric acid. Notwithstanding that it was a British chemist who pointed out the possible use of platinum as a catalyzer for the oxidation of sulphur dioxide, it was left to German chemists to bring the process to practical use.

The work in hand is interesting as a joint production of British and American authors. It illustrates in a pleasing manner the practical extension of "hands across the sea" which it is hoped will continue to develop until the two great English-speaking nations will be as one in all purposes and sentiments.

That the work is a second edition does not appear on the title-page, an unexplained departure from the usual course, but the fact is stated in the copyright notice and on the back of the book and the preface to the first edition is reprinted. The work contains a vast amount of information on a very important and highly interesting department of chemistry.

HENRY LEFFMANN.

PRACTICAL COLLOID CHEMISTRY. By Wolfgang Ostwald, University of Leipzig, with collaboration of Doctors Wolski and Kuhn. Translated by Dr. I. Newton Kugelmass, Yale University, and Theodore K. Cleveland. xvi–191 pages, 22 illustrations, 12mo. New York, E. P. Dutton and Company. Price, $2.25.

This is a translation of the fourth edition of the German original of which three editions were exhausted in two years. An examination of the text shows that it well deserves its popularity. Colloid chemistry has grown to such great importance in both pure and applied phases, and the output of literature both in journals and in books is so great that teachers have been swamped almost completely. Works on physical chemistry give space to the description of colloid phenomena and experiments for illustration, and the special works on colloid chemistry also furnish data. The work in hand is simply a large collection of concise and clear descriptions of methods of obtaining colloids and of demonstrating the nature and character of colloid phenomena. From the large and varied data set forth in excellent form, the student and the teacher of the subject will find abundant material for study and demonstration. Enough of principles is given to aid in understanding the nature of the phenomena, but the greater portion of the space is taken up with what the book claims to be "Practical Colloid Chemistry." Though the senior translator is connected with an American university the book was made in England and, therefore, uses the peculiar British spelling for such words as "color." It is not clear why such heavy calendered paper was used, but the price of the book is satisfactory. The translation is well done.

HENRY LEFFMANN.

PROCEEDINGS OF THE OPTICAL CONVENTION, 1926. Two volumes, of a total of 1051 pages exclusive of preliminary texts and indexes, large 8vo. Published by the Optical Society, London. Price, £3, net.

These volumes comprise a large series of papers presented at a convention held in London in April, 1926. In addition to the scientific contributions a great many optical and general scientific instruments were exhibited, information about which is given in a catalogue which accompanies the volume of proceedings. The contributions and the exhibited instruments took a wide range. Both the catalogue and the volumes of proceedings are elaborately illustrated. Examination of these shows how highly specialism has developed and the variety of investigations that have been made in connection with the subject. Light is, indeed, our most important sense. Without it we could have no real consciousness of environment. The sense is widely extended through the animal kingdom, though it seems to be represented among very low organisms by merely a reaction to the radiant energy and not a definite

vision. Pure and applied phases of the subject are both well represented. Out of the large collection of valuable papers it is somewhat invidious to refer to any, but especial interest attaches to Lord Rayleigh's studies of silica glass on account of the peculiar optical properties of it, apart from its valuable qualities in the laboratory where it has materially relieved the platinum stress. The fact that crystallized quartz produces the transparent glass, while ordinary sand gives only a translucent form, is explained by the author of the paper to be due to the fact that sand is produced by the weathering of granite and contains water and carbon dioxide, which produce bubbles. Ordinary quartz crystals contain very little of such impurities.

Each paper is preceded by a short abstract. Considerable attention is given to projection apparatus and to color problems. The physiologic problems connected with the prescribing of glasses also receive expert consideration. It is not possible in the space available to give further data in regard to the contents of these volumes, but they will be found to be rich in information on almost all fields of the theory and application of light. They are most excellently printed and carefully edited. HENRY LEFFMANN.

THE RAYON INDUSTRY. By Moïs H. Avram, B.Sc., M.E., New York University. xxi–622 pages, 171 illustrations, small 8vo. New York, D. Van Nostrand Company, 1927. Price, $10 net.

Rayon is now well known to be the technical name of the cellulose products formerly called "artificial silk." The industry has grown to an enormous extent and the present work sets forth in great detail and thoroughness the methods used, as well as the general history. As with all other phases of progress in pure or applied science, it is difficult to say who was the originator. It appears from an interesting and carefully prepared historical note that the distinguished physicist and naturalist, Réaumer, stated in definite terms in 1754 that the manufacture of a fiber similar to silk was possible and would probably be some day accomplished by the use of gums and resins, these being at that time the only materials that seemed sufficiently similar to silk for the purpose. Nothing was attempted along this line. The discovery by Schoenbein in 1845, of the methods of nitrating cellulose, gave at once an impulse towards the manufacture of threads which should be of similar use as the well-known textile fibers. In 1855 a patent was taken out in France by Audemars for the manufacture of nitro-cellulose into threads that he called "artificial silk." It is worthy of note that the tendency has always been and still is to call these artificial fibers a "silk," although their chemical relation is to vegetable structures. However, they are more like silk physically for that is structureless, while the other natural textiles are organized.

Notwithstanding these adumbrations in the manufacture of an artificial textile, little practical result was obtained until a systematic investigation by Count Hilaire de Chardonnet, employing not only his own results but those of other workers, culminated in the successful production on a commercial scale and in satisfactory form, of the fiber at first generally known as "artificial silk." Chardonnet has been called the "Father of the Artificial Silk Industry." The progress of research brought into practical operation several processes for the production of merchantable fibers from cellulose. The first products were

cellulose nitrates which were denitrated after having been made into fibers. In 1890, Despeisses developed a manufacture by dissolving cellulose in ammoniacal copper solution. Then followed the "viscose" product in which a cellulose xanthate is used. Cellulose acetate had been the most recent development but while it has found rather extensive application as the "slow burning" film for motion pictures, it appears from the statistics for 1924 given in this book, that it constitutes but a small proportion of the rayon output, the bulk of which (76 per cent.) is viscose.

We have in this work a comprehensive and clear statement of the development and present methods of the great industries devoted to the manufacture of artificial fibers, and to all operating in such industries or desiring information concerning them, the book will be of much service and its appearance is timely. Notwithstanding this, it appears to the reviewer that the canons of criticism will not be fully observed if something is not said as to the form and plan of the work. It is in some respects a sad example of what such a book ought not to be. It is loaded with expensive photogravures that have no value to the user, whether operator or inquirer. Bird's eye views of plants, and a large plate showing workmen leaving a factory, add nothing to the information sought by the users of the book, and add much to the cost of production, not only for the plates themselves but for the highly calendered paper required for them. The result is a very heavy book for which the publisher must charge about twice what a properly written account of the industry would require. The text is often carelessly written, plural forms of verbs being used where the singular is required. Drawings of the appearances of the common natural fibers under the microscope are given. These can hardly be necessary in such a work, as the industry does not consider such data. The drawings themselves are not especially commendable, and are not altogether typical. Considering the extent to which photogravure has been used in the book, it seems that photomicrographs should have been used, if such additions were considered necessary. As a matter of fact, information on the structure and nature of natural fibers is attainable in other works and is, as said above, of little interest to those interested in this new and extensive industry.

HENRY LEFFMANN.

THE MYSTERY OF MIND. By Leonard T. Troland, S.B., A.M., Ph.D., Assistant Professor of Psychology, Harvard University; Fellow, American Physical Society, Etc. xi–253 pages, 21 × 15 cm., cloth. Illustrated with diagrams and drawings. New York, D. Van Nostrand Company, 1926. Price, $3.

"The parts of modern thinking have grown faster than the whole," wrote Baker Brownell in "The New Universe." Several efforts have been made in recent years to dovetail these parts together.

In 1921 Scudder Klyce, an ex-navy officer of Winchester, Mass., brought out his "Universe," proclaimed to be "a veritable solution of the 'Riddle of the Universe.'"

In 1922 "Tertium Organum," announced as "The Third Canon of Thought" (a key to the enigmas of the world) by P. D. Ouspenky, translated from the Russian by Nicholas Bessaraboff and Claude Bragdon, was published.

"Manhood of Humanity" by Count Alfred Korzybski, issued in 1921, pro-

claimed itself to be "The Science and Art of Human Engineering." Its theme is not "the universe." Yet, in making its analysis of "Humanity's" place in the universe, a critique of the entire cosmic scheme is offered. Other works have incorporated similar attempts to "bridge together" the parts of modern thought into a unified system. They have aimed to help "the whole" of modern thinking to catch up with "the parts."

Doctor Troland's contribution to this task of cementing the sciences into a sort of "United States of America" is at least interesting.

When Sir Joseph John Thomson, of Cambridge, opened his series of talks at The Franklin Institute in April, 1923, he called attention to the fact that the study of the proton and the electron, as the components of all material substance, had given all the physical sciences a common interest and had practically made physics and chemistry a single science.

The author of "The Mystery of Mind" evidently considers that this situation, in which science finds itself to-day, offers an invitation to psychologists to enter into this "unified field."

At the Institute, January 24, 1924, his paper was read, presenting his views as to "The Interrelations of Modern Physics and Modern Psychology." He postulated a "universe" characterized by electrical phenomena; and centred his attention upon the human brain. The electrical "double layer" or condition of "polarization," following the contour of the individual nerve fibres, and accumulated in the brain, he conceived to be the "key" to the source of mental activities. To this source he gave the name "central synergy."

The book by Doctor Troland builds upon this foundation. It assigns electrical action to all phenomena, objective as well as subjective. The interpretation of this activity, as essentially identified with a certain kind of "consciousness," leads to his fundamental concept; namely, that of "a general sentient universe."

This position Doctor Troland properly identifies as a species of "panpsychism." No physicist would quarrel with such a position when understood to be a structure of philosophical or psychological thought.

However, the author advances his argument. He writes: "We can state truthfully that this world cannot be conceived as real, unless we give it a panpsychic interpretation."

Physicists would of course take issue with this statement. As Norman Campbell, Sc.D., pointed out in the JOURNAL of December, 1924, "When physicists speak of a 'real world' or of 'objects existing,' they are not referring to the philosophical conception of reality or existence at all. Real or existent things for the physicist are those concepts which satisfy completely his intellectual instincts, that is to say, either the concepts of laws or the concepts of theories which explain those laws."

That Doctor Troland realized he had entered into what might be controversial ground is shown by his comment, "To believe in the existence of a general sentient universe requires considerable intellectual courage." Furthermore, he recognizes that "the real problem is that of the relationship between consciousness and the physicist's theory."

Undoubtedly he has in mind by "the physicist's theory" practically the same thing that Doctor Campbell means by that class of scientific concepts which

he states are not "real" (see footnote to Doctor Campbell's article in the JOURNAL, p. 825).

We are bound to congratulate the author of "The Mystery of Mind" for going through with his proposition to the best of his ability and making use of the best data he could find. In his book is collected a large store of very interesting and valuable information. The method by which it is brought together, as he develops his thesis, gives to the work a touch of originality not to be disparaged.

With real good humor Doctor Troland concludes by admitting "we cannot hope in the present book to make such a doctrine really clear. To do so would be too difficult and if successful would unduly dispel the 'mystery of mind'; which it had been our purpose to set forth rather than to solve."

JOHN W. STOCKWELL.

THE PROPERTIES OF INORGANIC SUBSTANCES. By William Segerblom, A.B. Second revision, 226 pages, 8vo. New York, The Chemical Catalog Company, 1927. Price, $6.

The first edition of this work was issued in 1909; a second edition with minor changes appeared in 1916. The present issue is modestly called a second revision, but involves a considerable amount of new matter with changes in data made necessary by the publication of results of investigation, especially with reference to the International Critical Tables. No fault can be found with the information furnished which comprises a wide variety of data concerning inorganic substances. In addition to strictly scientific data, common and trade names are abundantly given.

The form and method of the book do not seem to the reviewer to be the best. Book manufacturing is to-day a very expensive procedure; the amount of literature required by the teacher and worker is enormous and is increasing in an accelerating ratio. It behooves authors and publishers, therefore, to economize type and paper as far as may be done without sacrificing clearness and durability. It does not seem that the common or trade names are needed in such a volume. It will be almost entirely, if not quite entirely, used by trained chemists who will consult it for specific data and who care little for the fact that lead hydroxycarbonate is known as hydrocerusite, or that potassium chromate is termed tarapacaite. The main arrangement is based upon Fresenius' grouping of the metals, but in a work of this character not in any way intended for consecutive study an alphabetic arrangement would be quite satisfactory. After all the large amount of miscellaneous data accumulated would be better set forth in tabular form than in that of paragraphs. The condensed arrangement is somewhat difficult to consult and involves a large amount of repetition.

HENRY LEFFMANN.

A TEXT-BOOK OF INORGANIC CHEMISTRY. Edited by Dr. J. Newton Friend. Vol. 3, part 2, Beryllium and Its Congeners. By Joshua C. Gregory, B.Sc., and May Sybil Burr, D.Sc. xxiv–342 pages, illustrated, 8vo. Philadelphia, J. B. Lippincott Company, 1926.

This is a continuation of the well-known extensive series of descriptive inorganic chemistry. The amount of data included in the work is enormous and

its usefulness is increased by careful and systematic arrangement and comprehensiveness and thoroughness of the references. Year and volume are given in each case. The periodic system is followed, and a table of this is printed with each volume. An item deserving special mention is the printing in each volume of a table showing the chronology of scientific journals with the coincidences of their issues. Many authors give references in which either volume or year are missing, and if, as may easily happen, the given datum is in error there is no ready clue, but if the other datum is given (year or volume, as the case may be) the reference may be traced. On one occasion the present writer was seeking a reference and found "vol. iv," without the year. It happened to be known that the volume number was much too far back to be correct for the information sought. As a matter of fact the volume was 55. This shows also that Roman numerals are unsuited for references. The present work uses properly the heavy faced numbers. In the above case "iv" was simply a misprint for "lv" an error that could not have occurred if the Arabic (really Hindu) numerals had been used.

The elements included in this volume comprise both somewhat uncommon and very common ones, beryllium and cadmium being of the former type and magnesium, zinc and mercury of the latter. So many volumes of the series have been already in the hands of chemists and have been found satisfactory in all respects that further exposition will be unnecessary. One matter of criticism has been mentioned in connection with volumes previously reviewed, namely, the awkwardness of designating the successive issues as "parts." It is not likely that objection to this will be regarded, for British authors and publishers seem to be attached to the system. HENRY LEFFMANN.

THREE LECTURES ON ATOMIC PHYSICS. By Arnold Sommerfeld. Translated by Dr. Henry L. Brose. 70 pages, diagrams, 12mo. New York, E. P. Dutton and Company. Price, $1.

Written in the clear and lucid style which is characteristic of the book on atomic structure by the author—"Atombau und Spektrallinien"—these lectures, delivered at the University of London, form a welcome supplement to the above treatise. In this discussion the author gives a résumé of the important ideas developed during the last two years, in the arithmetic of the spectrum, if we may use such a phraseology, and in particular of the relation of the chemical constitution of the atom to spectral structure. The first lecture deals with the discovery of the similarity of the hydrogen and alkali spectra and the validity of the relativity formula for fine structure. This naturally leads to a discussion of the summation rule for intensities of components of any line and the recent extension to series of multiplets. The second lecture deals primarily with Pauli's "Principle of Uniqueness" which determines the exact electronic configuration in terms of four suitably chosen quantum numbers. The specification of the electronic path in terms of four parameters has given rise to many attempts to explain the fourth degree of freedom, of which the most notable is Goudsmit's. The last lecture deals with the application of this principle to chemical linkage: The stable subgroups of the electronic shells which spectroscopy demands lead

to a theory of the non-polar bond between the atoms in the tetrahedral crystal structure of carbon in certain forms and of the ZnS and compounds of various other elements which crystallize in this system.

ARTHUR BRAMLEY.

PHOTOGRAPHY: ITS PRINCIPLES AND PRACTICE. By C. B. Neblette, Texas A. and M. College. xviii–644 pages, numerous text-illustrations and plates, 8vo. New York, D. Van Nostrand Company, 1927. Price, $6.50.

Of the matter of the book much praise may be said. All through the text it is evident that the author is familiar with the practice as well as the scientific data of photography as far as these are known. American work has been very fertile of recent years in the advancement of knowledge of the intricate chemistry and physics of the action of light on silver halides. It is perhaps to be regretted that most other sensitive substances have been left unstudied or studied only to a limited extent. The cause of this selection is not hard to determine. Silver halides have proved to be the best substances for the modern requirements of photography, especially in the high sensitiveness that may be given to them and the comparative permanence of their emulsions as prepared for commercial use. The immense development of photography has not been entirely due to its scientific applications. The invention of the dry plate and its later substitute, the flexible film, have placed in the hands of every one simple facilities for taking pictures, especially in travel. "You push the button and we do the rest" has meant delight to many millions and big business to many companies.

Amateur or professional photographers will find a large amount of accurate information in this book and the author is to be commended for compiling the data. These encomiums pronounced, the reviewer feels compelled to present a less favorable side of the criticism. The book is too big for the amount of information in it. It is loaded with unnecessary illustrations, which add to the expense without adding information. A highly expensive double spectral plate of colors is wholly useless to either amateur or professional. Many illustrations of standard apparatus, such as cameras, printing and enlarging outfits and illuminators are given. These are mostly taken from manufacturers' catalogues and furnish no information that cannot be obtained from such catalogues or from dealers. Some carelessness is shown in the use of vowel marks in proper names. They are, indeed, nuisances but it is hardly permissible to write, as is frequently done in this book, Lumière, Niépce and Lüppo-Cramer without these marks. Not enough is said about developing after fixing. It has, of course, not much practical value, but it is an interesting procedure. The item is not indexed, and the brief allusion to it on page 208 terms it as a "physical" development, thus adopting Lumière's inappropriate designation. If the precipitation of the metal by the development is not "chemical," what is it? No mention is made of the procedure with a mercury salt which is quite satisfactory.

In the preface the author speaks of a German work of Eder which he regards as not of the nature of a text-book, but he seems not to be aware of the small work by the same author, which is sold at a price equal to less than two dollars American currency, and contains a far larger amount of information in a much more compact form than this volume.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report 246, Tables for Calibrating Altimeters and Computing Altitudes Based on the Standard Atmosphere. By W. G. Brombacher. 24 pages, illustrations, quarto. Washington, Government Printing Office, 1927. Price, ten cents.

This report was prepared by the Aeronautic Instruments Section of the Bureau of Standards under research authorization formulated and recommended by the sub-committee on aerodynamics and approved by the Committee.

During 1925 the assumption of an isothermal atmosphere which was in general use as the standard for the calibration of altimeters in the United States was replaced by a standard atmosphere which assumes an altitude-temperature relation closely corresponding to the average of upper air observations at latitude 40° in this country. The same standard atmosphere had already been adopted somewhat earlier in the United States as the aircraft performance standard.

National Advisory Committee for Aeronautics Technical Reports Nos. 147 and 218 give necessary constants, tables and information. However, neither of these reports includes all of the tables required for the computation of actual altitudes nor those readily suitable for use in calibrating altimeters, since the altitude intervals for which data are given are not sufficiently small. The present report has been prepared specifically for these purposes.

The formulas which define the standard atmosphere are given in this report, together with other formulas giving the corrections to be applied to the standard altitude in order to obtain the actual altitude when the necessary observations of pressure and temperature are available.

The tables necessary for the use of this standard atmosphere in calibrating altimeters and in computing altitudes form the principal part of this report. An example of the computation of actual altitude from the necessary observation of pressure and temperature is also included.

Report 249, A Comparison of the Take-off and Landing Characteristics of a Number of Service Airplanes. By Thomas Carroll. 12 pages, illustrations, quarto. Washington, Government Printing Office, 1927. Price, ten cents.

This investigation, which is a continuation of Technical Report No. 154, "A Study of Taking Off and Landing an Airplane," follows very closely the earlier methods and covers a number of service airplanes, whereas the previous report covered but one, the JN-4h.

In addition to the air speed, acceleration, and control positions as given in Report No. 154, information is here given regarding the distance run and the ground speed for the various airplanes during the two manœuvers.

PUBLICATIONS RECEIVED.

The Rayon Industry, by Moïs H. Avram, B.Sc., M.E. 622 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1927. Price, $10.

Proceedings of the Optical Convention, 1926. Two parts, illustrations, plates, portraits, quarto. London, Optical Convention. Price, £3 net.

Optical Convention, 1926. Catalogue of Optical and General Scientific Instruments. 326 pages, illustrations, quarto. London, Optical Convention, 1926. Price, six shillings net.

Catalysis in Theory and Practice, by Eric K. Rideal and Hugh S. Taylor. 516 pages, illustrations, 8vo. London, Macmillan and Company, 1926.

Applied X-rays, by George L. Clark, Ph.D. 255 pages, illustrations, 8vo. New York, McGraw-Hill Book Company, 1927. Price, $4.

Outlines of Physical Chemistry, by George Senter, D.Sc. 421 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1926. Price, $3.

Swoope's Lessons in Practical Electricity. An elementary text-book. Seventeenth edition, rewritten, revised and enlarged, by Erich Hausmann, Sc.D. 694 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1927. Price, $2.50.

The Dial Machine. An apparatus for the elementary mathematical laboratory, by T. C. J. Elliott. 98 pages, plate, 12mo. Peterborough, England, The Peterborough Press, Ltd., 1926. Price, 4 shillings 6 pence.

A Text-book of Chemistry, edited by J. Newton Friend, D.Sc. Volume 3, part 2, Beryllium and Its Congeners, by Joshua C. Gregory and May Sybil Burr. 342 pages, illustrations, 8vo. London, Charles Griffin and Company, Ltd.; Philadelphia, J. B. Lippincott Company, 1926.

Properties of Inorganic Substances. A second revision and enlargement of tables of properties of over fifteen hundred common inorganic substances, by Wilhelm Segerblom, A.B. 226 pages, 8vo. New York, The Chemical Catalog Company, Inc., 1927. Price, $6.

Interpolation, by J. F. Steffensen, Sc.D. 248 pages, illustrations, 8vo. Baltimore, The Williams and Wilkins Company, 1927. Price, $8.

Photography, Its Principles and Practice. A manual of the theory and practice of photography designed for use in colleges, technical institutions and by the advanced student of the science, by C. B. Neblette, A.R.P.S. 644 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1927. Price, $6.50.

Recent Developments of Cosmical Physics. J. H. JEANS. (*Nature*, Dec. 4, 1926.)—In this lecture, delivered at the University College, London, on November 9, 1926, one of the ablest of cosmical scientists presents a consistent and comprehensive statement of the structure of stars and nebulæ as he conceives it to be. There are in the field other views, such as those of Russell and Eddington, and eventually from the clash of conflicting opinions there will, no doubt, emerge a theory taking into account all known facts and explaining all observed phenomena. In the meantime it is worth while to give attention to the surprising conclusions reached by Professor Jeans.

The lecturer calls attention to the transfer of the interest of astronomers from the solar system to the universe as a whole. They now find their main interest in the stars. Similarly to the physical astronomer the star is the centre of thought and of investigation. "From a study of the radiation emitted by the stars, the physical astronomer tries to unravel their physical structure, to discover how they generate their energy, and by what mechanism this energy is transmitted to their surfaces and discharged into space as radiation. In this way he may perchance happen upon properties of matter

which have eluded the terrestrial physicist owing to the small range of physical conditions at his command. His ultimate aim is to weld cosmical physics on to terrestrial physics so as to form one all-embracing science."

Physical astronomy had its birth when Huggins in 1863 used a spectroscope in conjunction with a telescope and discovered the identity of certain stellar lines with lines obtainable in the laboratory. There was much of error in the conclusions drawn from the early observations made on the spectra of stars, but the studies of Saha in India and of Fowler and Milne in the West show that the same matter in different stars will give rise to different spectra provided the temperatures are different. The spectra of the stars thus enable their surface temperatures to be deduced, and from the surface temperatures the quantity of radiation sent out from a unit of surface in a unit of time can be calculated. One square inch of the sun in a minute radiates 560,000 calories, the energy delivered by a 50-horse-power engine. "The hottest stars of all probably radiate at least a thousand times as much per square inch of surface." The total energy radiated from the star in a unit of time can be calculated when its apparent brightness and its distance are known. By dividing the total radiation by the radiation per unit of surface the area of the star is obtained and its radius and volume as well. "Calculated stellar radii range from about 300 times the sun's radius for Betelgeux to about 0.03 times the sun's radius for the companion of Sirius." Two other methods exist by which the radii of stars can be found, for the largest stars the Michelson interferometer method and for small stars the shift of spectral lines toward the red predicted from the Theory of Relativity. The application of these two means of measurement to Betelgeux and to the companion of Sirius gave dimensions in excellent agreement with the other method described above.

What is the state of matter in the stars? From the agreement of the calculations of size just mentioned, the author concludes "that Betelgeux and the companion of Sirius are neither transparent nor solid bodies, but full radiators like the sun. It seems reasonable to suppose that all stars are full radiators and so, as regards their mechanism of radiation, are essentially similar structures." It is commonly believed that matter at the centre of stars is made up of nuclei stripped of electrons and of electrons stripped from the nuclei to which they formerly belonged. These move freely like the molecules of a gas, the electrical forces that once bound the electrons to the nuclei being impotent in the whirl and clash of particles due to high temperature. Recombination is still further impeded by quanta of radiation that travel through the seething space. Descartes in 1644 seems to have had a premonition of some such condition in stars. From the centre to the circumference of the star the temperature falls and away from the centre there exist nuclei with electrons attached. At the surface of cool stars even molecules may be found.

Emden has calculated that the central temperature of the sun is 31.5 million degrees. "Indeed, Russell has recently suggested that the great majority of stars have central temperatures fairly close to 32 million degrees." At Emden's temperature the pressure of radiation amounts to about 2500 million atmospheres, yet this enormous pressure is only about 5 per cent. of the gas pressure at the centre of the sun due to the atomic fragments and electrons.

How does energy make its way to the surface of a star? In the interior there are three types of carrier, nuclei, electrons and radiation. Radiation exceeds the two others in free path and speed. Thus most of the energy arriving at the surface comes in the form of radiation.

On what does the size of a star depend? The author says, "I have shown that a star of given mass can rest in equilibrium with any radius from zero to infinity, different radii corresponding to different rates of generation of energy from zero to infinity by the star. A star adjusts its radius to suit its rate of generation of energy, and in so doing fixes its surface temperature and spectral type. Contrary to common belief, an increase in a star's rate of generation of energy is found to result in expansion and cooling." This statement is confirmed by the comparison of stars with almost the same mass, for example the sun and α Cent. B. The sun generates 36 per cent. more energy per gram than the latter. The sun's temperature is 5750° at the surface, while the other star's is 3000°. The radius of the sun is just about half of that of the other. The normal star grows smaller and hotter, then changing expands and cools.

It is possible to get some idea of the atomic weight of stellar matter. When such data as are available are collated, they point in the case of most stars to values of the atomic weight higher than that of uranium, the heaviest element. Moreover the younger stars have larger atomic weights than the older ones. Thus there seems to be an evolution of matter from high to low atomic weights, that is from complex to simple, as is the case in the radio-active substances with which we are familiar.

Kramers calculates that the density at the centre of a star is at least 100 times the mean density. In addition to this there is reason to hold that the heavier elements seek the centre, while the lighter elements appear at the surface. It is, however, from the surface that we derive the light which is our sole source of information for stars. We thus learn only of the lightest elements in the star. "It is natural that the earth, formed originally out of the sun's outer layers, should contain precisely the same chemical elements as these outer layers, but it now appears that there ought to be heavier elements inside."

How can a star radiate energy for so long a time? It is the young stars that radiate most energy per unit of mass, yet the total radiation from any star up to the present time furnishes a problem that needs

solution. The shrinking toward the centre of the mass of the sun or the impinging of meteorites on its surface are inadequate explanations of the duration of its heat. Since the coming of the Theory of Relativity we have become familiar with the equivalence of mass and energy and herein lies the solution of the question. "Throughout a star's interior, electrons and protons (hydrogen nuclei) must at intervals fall into one another and mutually destroy one another, the energy of their fall being set free as radiation. The energy of this fall is enormous. In no other way can a given mass of matter be made to yield energy of amount comparable with this; for example, whereas the ordinary combustion of a ton of coal provides energy enough to drive an express locomotive for an hour, the annihilation of a ton of coal would provide enough energy for all the heating, lighting, power and transport in Great Britain for a century." The duration of the sun's energy output is understood in part when it is known that only about one in every 10^{17} atoms of the sun annihilates itself in an hour. An additional argument for the existence in the stars of elements of great atomic weight lies in our inability to account adequately for the age-long emission of energy by elements that have atomic weights less than that of uranium.

Professor Jeans pictures matter in its earliest state as made up of elements of different atomic weight. Those with the highest atomic weight disappear first by annihilating themselves with the emission of energy. Those radio-active elements that we know on the earth are the remains of a much larger group, most of whose members are as extinct as the dodo or the carrier pigeon. It seems that we should seek in the nebulæ the elements of greatest atomic weight. When a proton and an electron annihilate each other the radiation produced has a wave-length of 1.3^{-13} cm. If this starts in the centre of a star, it impinges on a multitude of particles before it gets to the surface. At each impact its wave-length is increased by the Compton effect, so that it has become ordinary radiation by the time it leaves the star. In a nebulæ, however, the number of impacts is so small, owing to the low density, that the radiation will escape with little change in its wave-length and may well be that detected on the earth by Kohlhoerster and Millikan. Confirmation of this view is found in the fact that the radiation seems to come largely from the region of the Milky Way. G. F. S.

Chemiker Zeitung Semi-centennial.—Centennials, semi-, uni-, sesqui-, di- and poly-, have been much in evidence of late years. Mankind seems to be working up to appreciation of the past. The *Chemiker Zeitung* sends out a special number to celebrate its fiftieth anniversary, containing in addition to formal papers and the usual items, congratulatory letters from prominent chemists. Among

these we note a timely one from Dr. W. A. Noyes, who calls attention to the fact that no nation or group of peoples can claim to be originators of chemistry as a science. This is true indeed of all progress in knowledge. The claim made by Wurtz that "chemistry is a French science" was without justification.

Fifty years is not a great while in the history of general science and not even in chemistry. Liebig's *Annalen* is about five years from its centennial. The *Chemiker Zeitung* is, however, a little different from the general lot of chemical journals. It has a somewhat "newsy" character as we Americans would say, giving information as to the general progress and details of the science and not confining itself to formal papers or formal abstracts. We wish it many years of success and service to science. H. L.

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